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Horace W. LaBadie, Jr.

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Thanks also to Susan Moss of Laser Connection.

Introduction

This book explains the process of converting stock Canon CX and SX laser engines to full PostScript printing capability by the use of readily obtainable parts. The project is well within the technical competency of the novice electronics experimenter or builder: No special knowledge of computer architecture is required, and the only aptitude needed is that of wielding a soldering iron in a nonlethal manner. The expenditures of time, effort, and funds are not negligible, but the resultant improvement in the quality of printed output from any computer is so great as to easily justify the respective outlays.

The origin of this book

The origin of the concept of building a low-cost PostScript-capable laser printer is shrouded in the mists of mystery. Like so many legendary ideas, there are many possible candidates for the title of father of the home-brew PostScript printer. Certainly, Don Lancaster, the self-acknowledged PostScript guru, can rightfully claim to be at least foster father of the project, for it was he who first gave the idea currency in his columns for *Computer Shopper* and *Radio Electronics*. However, QMS had already been in the marketplace with their own conversion kits for more than a year when Lancaster announced that it was possible to do-it-oneself without resorting to the QMS products, PS-Jet+ and JetScript.

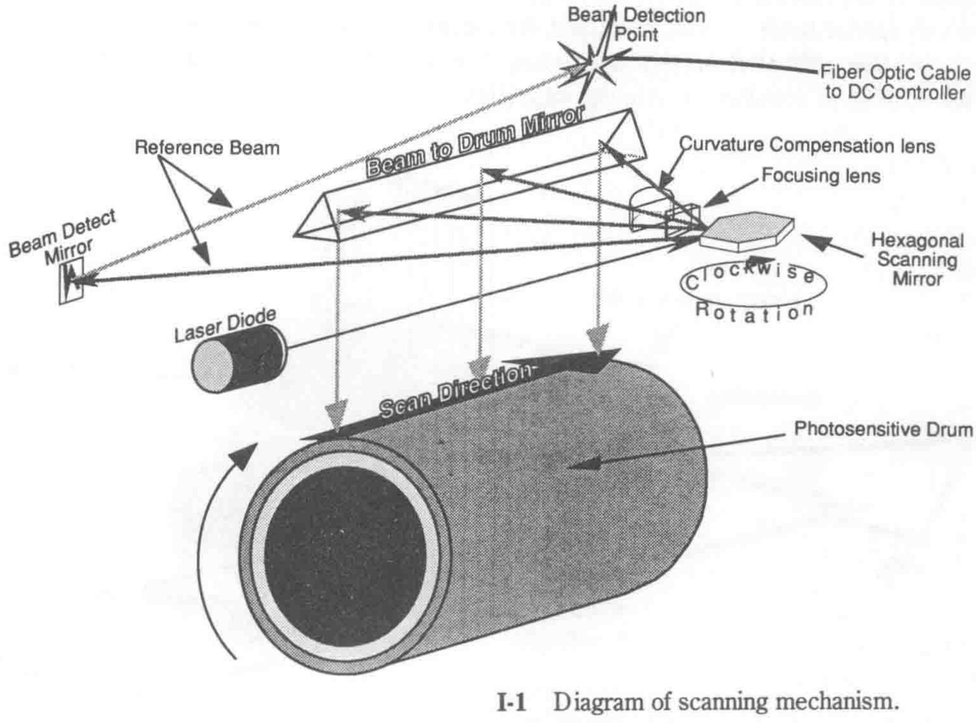
While Greg Saulsbury of Custom Technology did not invent the idea, he performed the early hard work in exploiting the potential of the notion and was the first to publish coherent plans for the conversion (see the Bibliography for more information). He, in turn, acknowledges the help provided by Chuck Morgan in starting the job. I came into the picture quite late, having purchased Greg Saulsbury's privately printed plans, and I followed the not well-beaten path that they laid. In June 1989, Greg published his revised plans in an article, "Building a Low-Cost PostScript Laser Printer" in *Computer Shopper*. In July 1989, I wrote a brief article, "Boys! Grow Giant LaserWriters in Your Basements!," intended as an addendum to Greg's article in June. I detailed some of the information I had accumulated by experience and filled in some gaps in the plans into which I had fallen during my own execution of the project. The article was eventually published in the January 1990 issue of *Computer Shopper*, and this book is the result of the favorable response which that publication received.

The beginning of personal laser printing

Canon, the Cyclopean Japanese giant, developed the basic mechanism of the laser printer in the 1970s as the foundation of its line of personal copiers. The success of those machines rested largely in the design of the toner cartridge, which contained all of the expendable elements of the copying process and was cleanly and rapidly replaceable by the end user. Of equal importance to the machines' success and to their remarkably low price (a vital factor of that success), but not equally appreciated by the general public, was the design of the laser and its scanning system. It was this design, the very heart of the machine, that made the affordable desktop laser printer an inevitable product. See Appendix A.

The semiconductor laser produces a beam of infrared light, all of one wavelength, in bursts a millionth of a second or less in duration, which can be focused to illuminate a spot as small as 100 microns, or approximately 4/10,000 of an inch square, giving a theoretical resolution of 2500 dpi. Although the laser is able to reach this fine pitch, a few multiplication operations show that practical printing cannot currently attain this level of resolution due to the limitations imposed by today's micro-hardware. For instance, the ordinary 300 dpi printer gets along quite well with one megabyte of ***random access memory*** (RAM), representing each dot by one memory ***bit*** (binary digit). However, the RAM required to address a 2500 dpi bit map on a typical 8×10 inch printed page would be on the order of 780 kilobytes (a ***byte*** is 8 binary digits or bits; a ***kilobyte*** is 1024 bytes) per square inch. These requirements make full page images impracticable, even with virtual memory, at current chip densities and processor speeds.

The scanning optics of the engine (Fig. I-1) use low-cost plastic elements.

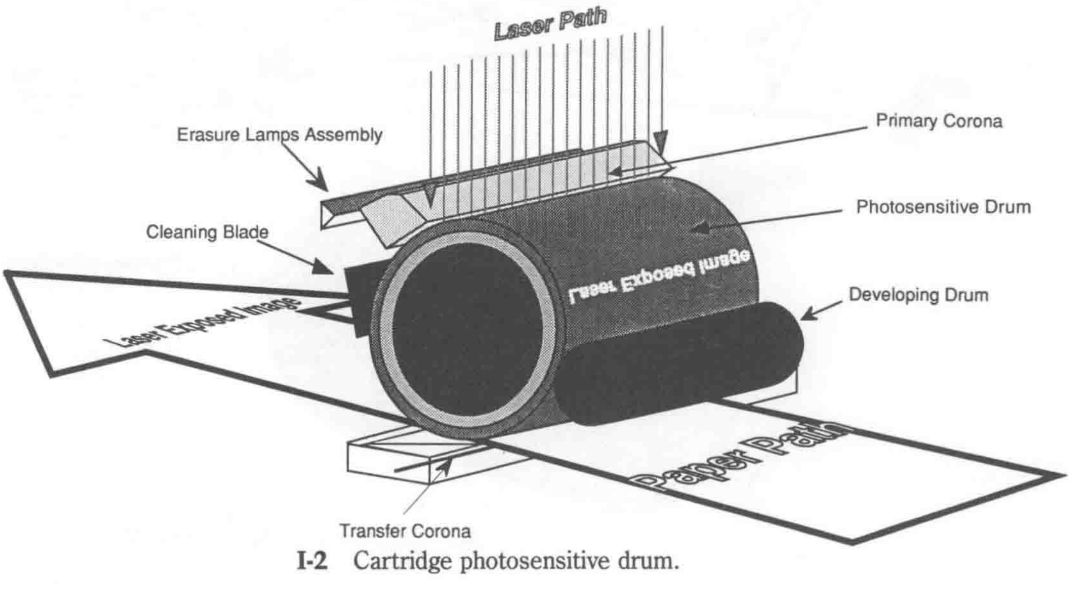


I-1 Diagram of scanning mechanism.

The engine paints the light bursts as pixels across the negatively charged photosensitive drum (Fig. I-2), dispersing the negative charge and attracting the toner particles at the developing station. The aluminum drum is coated with an organic photosensitive material, a characteristic of which is its high conductance (low resistance) when exposed to light, but low conductance (high resistance) in darkness. It is prepared for reception of the image by a rubber wiper blade within the cartridge and by erasure lamps that are embedded in the printer's upper half. These lamps impart a uniform low-resistance state to the drum's surface, allowing any residual charge in the photoconductive layer to be drained. The drum is then given a high voltage negative charge (−600V) over its entire surface. The laser beam serves to dissipate this charge by restoring the low resistance in the areas it strikes. The laser-exposed areas then have a −100V charge, while unexposed areas retain their −600V charge, thus creating the image to which toner is then applied. Toner is attracted to the exposed (lower negatively charged) areas. (See Appendix A for more detail.) The toner particles of a write black engine are a mixture of plastic resin and iron oxide that is projected to the blank page and then bonded to the paper by the heated rollers of the fusion unit, completing the process of printing.

Grouped together in a box, with other more mundane but necessary components, these elements form the basic laser *engine*. All of the laser printers discussed in this book use essentially the same engine. That is the reason that a rather witless printer, such as the HP LaserJet, or even the entirely brainless one, the NEC RPE-4502, can be made into an intelligent PostScript conversant machine.

At this point, it is appropriate to ask, "Why PostScript?" Why should you go to the trouble of acquiring PostScript capability?



I-2 Cartridge photosensitive drum.

Classes of desktop laser printers

Desktop laser printers with resolutions ranging from 300 to 600 dots per inch belong to that class of imagesetting devices called *page printers*. This category includes machines using laser diode, LED array, and liquid crystal shutter-driven engines (see Appendix A). The class of page printers is represented at the higher resolutions of 1200 and 2400 dots per inch by the print-to-film Linotronic and Compugraphic systems. Page printers primarily differ from the standard computer printers, such as impact and ink jet, in that they compile an in-memory image of an entire page and then transfer that image to paper in one operation, while the pin-headed printers print one line at a time, whether composed of a raster image or alphanumeric characters.

Laser printers are at the current upper limit of personal computer printing. They fall into two basic groups: Those that use or emulate the Hewlett-Packard and those that use or emulate the Adobe PostScript page description language. The Hewlett-Packard based printer is generally cheaper and therefore understandably more numerous than the PostScript-based machine. As you will see, they are virtually identical in all respects except for the language interpreter used in their controllers. Thus, it is possible to pay three or four times more for a true PostScript-speaking printer than for one which emulates the Hewlett-Packard LaserJets. It is possible, but not necessary.

Hewlett-Packard LaserJets

Of the two main camps competing for the laser printer market, that of the Hewlett-Packard (HP) variety is larger. Indeed, from the beginning of personal computer laser printing, the Hewlett-Packard LaserJet series has been the leader in both sales and in the number of imitations spawned. Hewlett-Packard brought the laser printer into the sphere of affordable computer peripheral when it introduced its Series One printer, based upon the Canon LPB-CX model laser engine. The Canon LPB-CX was a smarter variant of Canon's own extremely popular personal copier series. The price was low in comparison to previous laser printers from companies like Xerox, but, at about $2500 from even the discounters, it was still out of the reach of the majority of personal computer users. This prohibitively high price led to the development of the now multitudinous HP compatible copies from the manufacturers of traditional impact printers such as Epson, Panasonic, Okidata, and Alps, and to the collateral development of higher resolution 18, 24, and 27 pin dot matrix ribbon printers, at last bringing high quality printing to the great masses without the high cost.

Quite apart from the price, Hewlett-Packard and its compatibles enjoyed another advantage that led to its domination of the IBM/MS-DOS mainstream: They are in the direct line of descent from the older dot-matrix technology that grew up in an environment saturated by CP/M, the spiritual predecessor of MS-DOS. Because they are largely a superset of an extant technology rather than an altogether different species, the HP and compatibles have a natural adaptive advantage over PostScript printers. Only in their printing method and resolution do the HPs and compatibles differ from their hard copy cousins. At heart, the LaserJet is an upscale dot matrix printer.

At 300 dpi, the LaserJet:

- Offers higher resolution than the most advanced 24 and 27 pin impact printers, which top out typically at 244 dpi.
- Is faster, turning out an average page in about 15 seconds, as opposed to one page every 2 to 5 minutes in highest quality from the impact printers.
- Is quieter, with only its fan and paper feed mechanisms producing any noise at all, compared to the 50 or 60 decibels which emanate from the ordinary pin printer.

Those are its specific virtues. But, like the ubiquitous dot matrix, it creates text by matching the ASCII character codes sent to it with the character sets built into its read-only memory (ROM). As in the lowly dot matrix, those character sets are small in number and are resident only in a few point sizes. The page's text is composed by this translation of individual character codes into predefined bit maps. The text orientation on the page is limited to portrait (vertical) or landscape (horizontal) with a separate bit-mapped character set needed for each of the typefaces and page orientations. Additional typefaces are available by the insertion of font cartridges into a special slot in the logic board, accessed through an aperture in the lid of the printer. HP font cartridges contain generally one type family, but third-party developers have created multi-face cartridges of greater versatility and value. No special effects, such as type rotation, are possible, except as graphic images sent pre-formed from the host device; graphics are essentially raster images, albeit at 300 dpi. Vectored images, such as those used in CAD, are supported, but must be generated by the computer software that sent them to the printer. HP's extensive experience with plotters makes the LaserJet a reasonable choice for such work. Indeed, the latest (mid-year 1990) LaserJet, the Series III, includes plotter functions among its expanded page description language. The Series III also introduces internal outline fonts from Compugraphic, and HP promises more from outside developers in the future.

PostScript is now, and will continue to be, the standard from high end to low end in page description. The Series III is not PostScript compatible, although you can buy an optional 2 megabytes of RAM and PostScript cartridge. HP appears to be moving, like Apple, to avoid the added expense of PostScript licensing while attempting to ape its best features, but it is movement in the wrong direction. Unlike Apple and Microsoft, which are jointly developing a PostScript clone called TrueImage, HP continues to hold out even against PostScript compatibility. Most of the HP compatibles make a virtue of their limitations, boasting high-resolution emulations of the Epson, IBM, and Diablo impact printers, while using the drivers of the impact printers.

PostScript printers

The PostScript laser printer is a very different kettle of fish from the garden pond variety of dot matrix printers. Yes, it is a dot matrix printer in its mechanics, but it is wholly vector based in its page composition, both in text and graphics. (See Appendix A for more about how PostScript works.)

PostScript was specifically designed by John Warnock and others at Adobe to be a computer-based typesetting language. PostScript was not developed out of a previous technology, but was intended to be device independent, rendering any of its commands at the highest resolution offered by the machine in which it resided. Thus, for instance, a file created on a Macintosh and meant to be printed on an Apple LaserWriter, can be transported to any other computer of any type and, when transmitted to a PostScript device, be accepted and successfully rendered, whether the resolution of the destination device be 300 dpi or 2400 dpi.

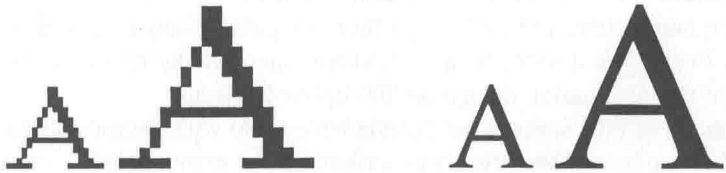
Because all of PostScript's commands have to do with vectors, any image (text included) that can be mathematically described can be manipulated in a nearly infinite number of ways. Text and graphics can be stretched, rotated, shrunk, twisted, placed in 2- or 3-dimensional perspective, shadowed, or made practically any shade of gray. (See Appendix A.) The only limit to the effects that can be produced in PostScript is in the user's imagination.

PostScript allows the ultimate freedom with the very minimum of means. If you have the patience and the fortitude, you can, with only the most rudimentary computer and text editor, create any typographic or pictorial effect without actually drawing a single line or dot. Thus a person stranded on a desert isle with only a Commodore 64, a text editor, and a PostScript printer can turn out the same camera-ready artwork as someone drawing at a Sun workstation using the most sophisticated CAD software. Of course, the marooned draftsperson will require magnitudes greater resources of time and brain power to accomplish the same task that could be completed quickly and easily on the minicomputer, but the point is that it can be done.

While actually plotting verbally in PostScript can be woefully inefficient, PostScript itself is wonderfully efficient. Because a particular text face, for example Times-Roman, exists in PostScript, not as a fixed number of dots or digital bits arranged in a fixed relation one to another, but as a series of mathematical calculations, a text face needs to be described only once for it to be available to the printer at any scale required from 5 to 5000 points. (A *point* is a printer's measure approximately 1/72 of an inch, which is, not by coincidence, also the screen resolution of the standard Macintosh monitor.)

In PostScript, one description truly does fit all sizes. For example, the characters on the left in Fig. I-3 are bit-mapped Macintosh fonts, the smaller being a 24 point screen font installed in the System and shown dot for dot as it was designed. The larger is the Macintosh QuickDraw rendition of 48 point Times Roman, expanded according to Macintosh ROM algorithms from the 24 point size. The characters on the right in Fig. I-3 are PostScript versions of 24 point and 48 point Times Roman, neither of which is resident in the printer ROM. The type face exists only as a generic set of mathematical descriptions from which any point size can be calculated. If the HP LaserJet uses a type face not in its bit-mapped character set and had to scale its resident bit maps to the requisite size, the results would be similar in aspect to that generated by the Mac's quick-and-dirty ROM, or it would fail to print altogether.

That is the *why* of acquiring PostScript. The rest of this book provides the *how*.



I-3 The difference between bit-mapped (left) and vectored (right) Times Roman.

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