Inter-Office Memorandum

To	Harold Hall Lynn Conway VLSI Systems Design Area	Date	April 6, 1981
From	Rich Pasco	Location	Palo Alto
Subject	Color Printer/Plotters	Organization	PARC VLSI Systems Design

XEROX

Filed on: [Indigo]<DA>RamtekPlotter>Printers.Bravo, .Press

Introduction

This report summarizes an investigation into color plotting devices appropriate for producing checkplots of VLSI circuit layouts. The goals of the investigation were to find a plotter optimized for low cost and reliability.

Types of Printer/Plotters

Impact. Like a typewriter, hammers push an inky ribbon against paper, with one hammer blow per pixel. These machines are simple in concept. The major drawback to impact printers is that ribbons need frequent replacing. Also, there are many moving parts subject to breakage and wear.

In the Ramtek 4100, there are four heads, each with a different colored ribbon, mounted on a single carriage which travels horizontally across the entire paper, marking eight rows of pixels (or one line of characters) at a time. Each head has eight hammers arranged vertically. It is possible to replace only one color ribbon, should it be used before the others.

In the Trilog ColorPlot, there are 44 hammers spaced horizontally about one-third inch apart across the 15" page, mounted on a carriage which shuttles about one-third inch back and forth. First every N-th dot in each line is printed, then the dots in between as the head moves. The paper advances one line and the process repeats. The ribbon has three sections spliced end-to-end, one for each primary color. A separate pass over the drawing is made for each color, with the ribbons rewound or fast forwarded in between.

Inkjet. A fine stream of liquid ink is squirted from a nozzle and deflected electrostatically between the paper and a gutter. Variations include: Whether the jets squirt onto a drum which transfers the image to the paper, or directly onto the paper. Whether the surplus ink in the gutter is recycled or discarded. How many jets and how they are arranged. The Applicon device produces beautiful plots on single sheets up to 34" wide, but its $40,000 price places it out of our reach. The PrintaColor IS8001 sells for $6,000, but its sample printouts are of uneven dot size, relatively poor registration, and inaccurate color rendition. Ink jet printers are reputedly prone to jet clogging; not too reliable.

Xerographic. An electrostatic charge is placed on a photosensitive drum, and a mechanically deflected laser writes an image, discharging the drum where it writes. Powdery toner is dusted over the drum, sticking where charge remains. Then the toner image is transferred to paper. The process is repeated for each of three primary colors, then the paper is heated to melt the toner and fuse it to the paper. Only known manufacturer is Xerox; plotter is based on 6500 copier; plotters known as Puffin, Pimlico, and CGP (color graphics printer). The latter is a Xerox product; others are research prototypes.

Electrostatic. Paper passes over an array of metal nibs which impart an electrostatic charge where printing is desired. The paper is next washed by a toner bath containing colored toner particles, which adhere to the static charge. Versatec and others make black-and-white printer/plotters; no color machine is known.

Thermal Dye Transfer. Paper is brought in contact with a web of special paper coated with a waxy ink as it passes over a head containing several hundred resistors. Spot heating causes the wax to melt and the ink to transfer to the paper. Fuji Xerox makes a black-and-white version; no known mfrs. of color version, which would require three print-head/web-transport assemblies.

Considerations when selecting a printer

(reliability, serviceability, etc.).

A more global view of our decision is not which commercial color printer to buy so much as how can we meet our color printing needs. A major advantage of using a Xerox color printer (e.g. Lilac) is the positive impression made on visitors. No printer manufactured outside would speak as highly for Xerox.

Ribbon Cost. One drawback for impact printers is the cost of replacing the inked ribbon. The Trilog 3-color ribbon costs $40; the Ramtek uses four colored ribbon cartridges at $10 each. Ribbon life seems to be comparable for both machines, between several dozen and several hundred plots, depending on the density of the plot and the allowable fading. Presently, for either machine the ribbon must be replaced when its ink is depleted, but Ramtek promises to release a re-inking cartridge, which would allow a ribbon to be used as long as the fabric lasts.

Software

One issue in considering whether to buy a color printer is the amount of programming which would be required on our part. Should it run Press? Or should a special program to do LSI plotting be used? Who is to write output module to drive the new printer? It appears that several person-months of programming would be required.

Press (the program) could be modified to drive an impact printer. Then Press files from arbitrary sources (e.g. Sil, Griffin) could then be printed. One major drawback to using Press is that the page length (hence aspect ratio) is set to a constant when Press is installed. It would thus be difficult to produce drawings of arbitrary height. Since Press delivers three single-color bitmaps on three passes, Press might be easier to interface to the Trilog than to the Ramtek.

Alternatively, a new output module could be added to the **Jam CIF** processing software. This would bypass the Press file format and its restrictions, eliminate the necessity of BCPL modifications to the Press program, and permit direct control of the plotter from the LSI plotting software (thus facilitating dedicated stipples, integral numbers of printer dots per lambda, etc). The disadvantage is the inability to print Press files from other sources (e.g. Sil, Griffin).   Since the Jam color plotting routines represent color on a pixel-by-pixel basis, the interface here to the Ramtek might be easier.

Perhaps some amount of software can be imported, although this is not likely to be too useful. For example, Bart Locanthes's CIF plotting program (see appendix) could be imported and translated from   C'' to Mesa.

Halftoning: image resolution vs. color menu. Halftoning is the process of using variable size dots to represent different intensities of each primary color. Most printers are not directly capable of halftoning; they make a binary decision for each primary color (strike or don't strike) on each dot. To produce a halftoned image on such a printer, the printer resolution must be much finer than the picture resolution, so that groups of printer dots may represent each picture element. Without halftoning (one picture element per printer dot) only seven colors plus white are available,

depending on whether or not each of the three primary colors is struck. The primary colors used are yellow, cyan, and magenta; in pairs one obtains red (yellow+magenta), green (yellow+cyan) and blue (cyan+magenta); all three colors at once produces black. But LSI checkplotting requires more than seven colors. At a minimum eight colors are required to represent metal (e.g. blue), diffusion (green), polysilicon (red), metal over diffusion (cyan), metal over polysilicon (violet), polysilicon over diffusion (brown), ion implant (yellow), contact cut (black), and overglass cut (brown). Using a 2 x 2 array of printer dots for each halftone dot could in theory produce 63 colors (0, 1, 2, or 3 dots turned on in each of three primaries), of which at least eight should be usable. In order that the halftoning pattern is fine compared to the details of the layout, at least two halftone dots or 4 printer dots should be used for each lambda. One such halftone stipple, similar to that used in the sample VLSI printout from Silicon Systems displayed at Group 3 Electronics, is shown in Figure 1. Here metal, polysilicon, and diffusion are represented by checkerboards in cyan, magenta, and green, with the green occupying the opposite polarity of the checkerboard from the magenta and cyan. Solid outlines help identify the boundaries of each layer.

Conclusions and Recommendations:

If the CSL xerographic color printer Lilac'' were serviced and maintained regularly, then in many applications it would be the printer of choice. When it is properly working it can produce prints of quality far superior to that obtainable by any other technology. However, the overall cost of keeping such a plotter readily available appears to be very high and is not presently provided for.

The VLSI Systems Design Area requires access to color plotting at all times. Thus I recommend that we buy an impact color printer/plotter for internal use as a checkplotting device when designing integrated circuits. This machine would provide more reliable service than Lilac, yield more legible plots than the black-and-white Versatec, and facilitate the generation of color wallpaper'' (poster-size plots).

Opinions as to whether the **Trilog ColorPlot 100** or the **Ramtek 4100** is better are nearly evenly split. As the appendix shows, users of both machines are happy with their purchase. Both machines are approximately the same price, $12,000. The Trilog process is established and reliable, but its multi-pass approach is a bit awkward. The Ramtek process is newer and potentially better, but suffers from minor but annoying design bugs supposedly being fixed. Trilog produces 100 dots per inch, whereas Ramtek produces 70, but color registration problems with the Trilog limit its practical resolution to about the same as, or slightly worse than, the Ramtek, which has nearly perfect registration. Present ribbon costs are comparable, but the advent of the re-inking cartridge will favor the Ramtek.

While either machine would be acceptable, my personal feeling is to favor the **Ramtek 4100**, because of its better registration, local manufacture, and potentially lower ribbon cost.

Appendix: User reactions

Responses from Trilog users:

Dave Ditzel
Bell Labs, Murray Hill
201-582-3655
3/25/81

Has been using **Trilog** plotter.
Quite nice; happy; satisfied.
Raster conversion software was fair amount of work.
Driven from CIF via program in C'' by Bart Locanthe. Same CIF software is up at CalTech; we could
        get a copy if desired.
CalTech is also happy with Trilog.
When new, would occasionally have 1-2 dots vertical registration error from paper rewind operation,
        due to controller bugs, now fixed.
Better to rewind and change colors after entire drawing. Used to do it after each page, but waiting for
        ribbons to rewind took too long.
Misregistration due to tractor-hole elongation not a problem.
Ribbon life: 24-hour/day use, 1 day; normal use, 1 week.
Resolution: At one dot per line width (2 l), can fit 1000 l per page and still verify connectivity. Don't
        usually do DRC by inspecting plots. Plotted 32-bit adder with carry lookahead on 1/2 page.
Best to convert entire file to raster first; can take 7000 disk pages of 1 kB each.
Don't know about Ramtek printer (didn't look at it when shopping).
They're doing M&C courses at BTL-MH, chips fabbed at BTL-Allentown.
Steve Johnson of BTL will describe their design environment at Computer Systems Seminar, April 2,
        1981, 3:30 p.m. Cory Hall, UC Berkeley.

Bruce Hunt
SRI
VBH.TSCA @ SRI-UNIX
(415) 326-6200 x5713
3/26/81

Using **Trilog ColorPlot** since early December 1980.
Intended use for VLSI checkplots, but software not written yet.
Have used it extensively for line-printer & simple plotting.
Super-reliable, never failed, zero problems, good quality.
Registration is not super-hot publication quality, but OK for in-house use. (Can see mis-registration if
        you use a magnifying glass.)
Biggest drawback is standing around waiting for ribbon to rewind to next color.
Didn't look at Ramtek; was not aware of it while shopping.

Mike Wimbrow
Silicon Systems
714-731-7110 x403
3/26/81

Had **Trilog ColorPlot** up since December 1979.
No major failures (only a few dirty board edge contacts).
Generally quite reliable.
Need to use good, heavy paper so solid color areas don't wear through & tear.
Need to be sure upper and lower tractors are properly aligned.
Paper rewinding: no special handling needed for plots up to 6 ft. long (just let it fall on the floor).
Registration is good enough in 6-foot plot for black standard-height text made by superimposing all
        three colors.
Slower than Versatec; we use Versatec for quick checkplots, Trilog for final going-over.

Bart Locanthe
Bell Labs & CalTech
201-582-7329
3/26/81

Trilog is nice device; no complaints with hardware design.
Trilog reps at New Jersey didn't know what they were doing, plugged Unibus interface cards in upside
      down, blew out backplane.
Two ways of doing CIF-to-raster scan conversion:
        Icarus/Versatec way (slow, but doesn't need much memory): For each scan line, see what
            items intersect it, and put them on scan line.
        Locanthe CIF/Trilog way (fast, but needs a lot of memory):
            Set up big bitmap for entire plot, then instantiate CIF; BitBlt everything into bitmap as
            it's found. Requires ~256 kB per page. No problem on VAX with 4 MB main memory;
            for Alto would need virtual memory on disk, would slow things down. Takes ~3 min.
            per page on VAX, including running printer.
CIF plotting code is available in C'', developed at Bell Labs by Locanthe, brought up unofficially'' at
      CalTech; would require formal release for Xerox, probably not a problem. CIF parser in
      YACC, scan conversion ~600 lines of C''.

Responses from Ramtek users:

Henry Fuchs
North Carolina Univ.
919-966-4650
3/26/81

We just bought **Ramtek** printer, serial number 2.
Haven't brought it up yet (it arrived damaged, awaiting replacement head).
Chose Ramtek over Trilog on design principals; feel 4 heads, 4 ribbons better than rewinding paper and
      ribbons.
Also rejected PrintaColor $6k inkjet; output looks bad: wrong colors, poor registration, etc.
Ramtek has given us excellent support on our four 9600 color graphics terminals.
Danny Cohen has Ramtek, serial number 1.

Danny Cohen
ISI
213-822-1511
3/26/81

We chose **Ramtek** because its one-pass approach looks inherently simpler.
We were afraid of misregistration problems which might occur with Trilog's three-pass approach.
Our software first writes to CRT bitmap, then dumps screen image to printer in one of two ways:
      (a) One screen pixel maps into one printer dot. Compact plot, but only 8 colors available (incl.
          white & black).
      (b) One screen pixel maps into 2x2 printer-dot stipple. Need bigger plot for same resolution,
          but wider variety of colors available.
Contact Vance Tyree for more details.

Vance Tyree
ISI
213-822-1511
3/26/81

We have Ramtek printer, serial no. 25. Only one other Ramtek in use in Southern California, at TRW.
Lots of hardware problems, infant mortality:
>   Lost five pin-driver transistors so far; one printhead is stuck.

Lots of minor firmware bugs:
>   Top-of-form position lost when graphics plot overflows a page.
>   Parallel interface does not exactly conform to Centronics standard.
>   Occasionally misaligns one pass left or right of previous by exactly one or two printer dots.

Except for third firmware bug above, registration is absolutely superb; far better than Trilog.
Ramtek provides excellent support; they seem to know what they're doing; confident they'll fix
>   firmware bugs soon.

Believe design is inherently far superior to Trilog, just needs time to shake bugs out.
Ribbons don't last very long (run out of ink after 3 hours continuous plotting) and they're doggone
>   expensive ($10 each times 4 colors). Re-inking cartridge will be a welcome relief.

Time to plot 512 lines of pixels at two printer dots per pixel (14 5/8" at 70 dots/inch) is about 7 minutes.
>   918 printer dots max. per line.

Driver software needs to keep track of when nine printer lines are sent, to initiate printing pass.

Manufacturer	Model No.	Technology	Primary Colors	Resolution Dots/Inch	Paper Size Inches x Inches Wide x High	Lambda [1] In.	Per Page Long Dim.	Time to print page, min:sec [3]	Interface	Price $
Ramtek	4100	Impact	4	70	(4-15) x (0-11)	.057	262	?3:00? "avg"	Centronics 8bit ||	$12,000
Trilog	ColorPlot 100	Impact	3	100	(4-15) x (0-11)	.040	375		Centronics 8bit ||	$12,000
PrintaColor	IS8001	Ink Jet	3	100	15 x 11	,040	375		RS-232C	$6,000
Applicon	CP 5586/M8	Ink Jet	3	127	34 x 22	.031	1080	8:30	|| Magtape emul.	$45,000 (1978)
Xerox	Puffin	Xerographic	4 [2]	384	8.5 x 11	.010	1056	0:27	Alto/SLOT	
Xerox	CGP	Xerographic	3	100	8.5 x 11	.040	212	0:27	Alto/SLOT	

[1]   Assumes four printer dots per lambda. Assumes printing to edges of paper.

[2]   But only three work on Lilac

[3]   Does not include Press formatting time.