INTRODUCTION

Graphics is one of the fastest growing applications of computer power. Users are finding easier and more sophisticated ways to apply graphics. The power of color graphics lies in its ability to present large amounts of information in an understandable way. People are using color graphics solutions to improve their presentations, make better decisions, and to lower costs. However, today's user can be overwhelmed by the different technologies and the sheer number of devices available. A buyer has more than 200 hardcopy devices to choose from.

This paper presents a guide to purchasing color hard copy devices. Today's buyer is looking for a graphics solution and not individual components. The hardest task for buyers is to define their needs. This overview of hardcopy technologies and key purchase criteria provides a framework for potential buyers. The framework will help users define their needs, and gain sufficient familiarity with color hardcopy to be able to communicate with salespeople.

WHY COLOR GRAPHICS

Graphics lead to efficient and effective use of information. Some of its benefits include shortening meetings, saving time analyzing data, improving decision making, and influencing others. Graphics and color provide extra dimensions to understand a message. An empirical study by the Wharton Applied Research Center found that 34% more of an audience will agree with your presentation if visuals are presented with your argument. More recently, a University of Minnesota study showed that presentations using visuals were 43% more persuasive than unsaid presentations.

Color helps present complex information by adding another dimension to graphics. Color can provide texture, richness, and flexibility. It can be used to selectively highlight, and emphasize a particular message. The University of Minnesota study found that using color graphics instead of black and white lead to improved audience comprehension and retention, which in turn lead to more persuasive presentations.

Color graphics achieve these benefits by focusing viewers' thoughts on concepts. A color image encourages the eye to compare different pieces of information. Studies of the brain have shown two ways of thinking; verbal (the left-side of the brain) and non-verbal (the right-side of the brain). The verbal way of thinking uses words and numbers to understand. The non-verbal way of thinking uses images, objects, and concepts to understand. Color graphics approaches non-verbal thinking to show trends, patterns, and inter-relationships. Consequently, color graphics turn data into information. A Hewlett-Packard study showed that an average person absorbs tables of numbers and words at a rate of 600-1200 words per minute. A person familiar with reading color graphics can comprehend information at a rate equivalent to 50-70 million words per minute.

OVERVIEW: COLOR HARD COPY TECHNOLOGY

Color hard copy technology can be categorized into impact and non-impact devices. Impact devices are dot-matrix printers and pen plotters. Non-impact devices are ink jet printers, thermal transfer printers, film recorders, and toner-based systems (electro-static, electro-photographic, and magnetic printers).

Impact devices currently dominate the market for hard copy from computer images. Dot matrix printers and pin plotters are in wide-spread use. They offer proven and reliable technologies.

Dot matrix printers use a series of wires impacting a colored ribbon to transfer ink to paper. The dots of ink are combined to form characters and images. Color graphics are created by successive printing of the same image in different colors. Color reproduction is limited because brightness and saturation cannot be controlled. Resolution is also limited by the size of the wires' diameter. Despite these disadvantages, dot matrix printers are popular due to their reliability and low cost.

Pen plotters are the mainstay of color graphics hard copy. Plotters draw lines very similar to the way we draw lines by moving a pen between two points. This device is well suited to drawing high quality line graphics (eg. bar charts, graphs). Line density, sharpness, and uniformity can be varied by using different types of pens. The colors available are limited to the inks in the pens. Similar to dot-matrix printers, pen plotters cannot control color brightness or saturation. One distinct advantage of this device is the ability to produce images on a variety of media (eg. transparencies, polyester film, vellum).

Ink jet printing is one of the most promising color hard copy technologies. These devices can combine text and graphics with excellent pictorial and color reproduction capabilities. Ink jet printers work essentially by spraying a stream of ink droplets onto the media. The ink jet is moved relative to the paper to create characters. A continuum of color is achieved by spraying color dots so small that the individual elements cannot be resolved. Light reflected from the adjacent colors is mixed in the observer's eye to create a single color. A range of colors is achieved by varying the pattern and amount of each color. Drawbacks of ink jet printers are that they require special paper and letter quality devices are very expensive. However, the ability to merge quality color graphics with text while maintaining a good throughput rate makes ink jet printers very attractive.

Thermal transfer printers are similar to ink jet printers. These devices use a heated pinhead to melt ink from a special ribbon and then transfer the ink to paper. A continuum of color is created in the same manner as ink-jet technology. These printers are small, light, inexpensive, and extremely quiet. However, they are relatively slower and more expensive to operate than ink jet printers. The thermal transfer ribbon can only be used once and special glossy paper is necessary to achieve the best results.
Color film recorders reproduce computer images with the highest quality available. A simple version of this device would be a camera photographing the terminal's CRT. More advanced systems integrate the CRT, camera optics, and film mechanisms. Color hard copy can be produced on slides, prints, and instant prints. The quality of the hard copy is currently limited by the graphics software and electronic components generating the image. Some drawbacks of these systems are the film costs and time needed to develop the film. However, film recorders offer the best color tone and fidelity available.

Electrostatic, electro-photographic, and magnetic printers are primarily available for black and white hard copy. These devices are toner based systems. The popular laser printer falls into this category.

Using different techniques, these devices create a latent image of the graphic on a drum in the printer. Areas of the drum are sensitized to produce the latent image. For example, a laser printer uses a laser to photosensitize the drum. The drum rotates through a toner which attracts ink particles to the sensitized areas. Then the drum transfers the ink to paper.

Color hard copy is currently produced by repeating the image formation–image transfer cycle several times with different color toners. That cycle slows throughput which is on the order of 6 pages per minute for black and white output. This class of devices is more useful for black and white hardcopy. Color hard copy applications of these devices are typically high volume production uses. These printers will become more useful in the future when better color technology makes low volume runs more viable.

Figure 1 summarizes the features, advantages, and disadvantages of each class of device.

GUIDE TO COLOR HARD COPY DEVICE PURCHASES

Of all the components in a color hard copy system, the printing device is the most critical component. The output device determines image quality, throughput rate, and color quality. Our framework for purchasing a color hardcopy device is to define your needs, find software to meet your needs, and then find hardware that supports your software and meets your hard copy needs.

The most difficult task is for buyers to define their current and future needs for color hard copy. Common mistakes are under-estimating the quality of the hard copy needed and the ways to apply color hard copy. Buyers under-estimate the high value applications of color hard copy and cannot justify the extra cost of more powerful and more flexible devices.

A good starting point is to make a detailed list of all the jobs that currently use or will use graphics. The jobs on the list will provide a good idea of the type of graphics system needed. Figure 2 shows a list of questions that also need to be considered in purchasing a color hard copy device/graphics system.

If the color hardcopy device will be part of a dedicated graphics system, then high throughput and the ability to run unattended are important issues. If many people are going to be using the system, then there are trade-offs to be considered in having a single centralized output device or several distributed devices. High throughput and unattended operation will be less important in a distributed system.

The level of quality is a key issue because so many buyers under-estimate that need. When color hard copy is intended for personal or informal use then presentation quality output is not necessary. However, later that same information may become part of a formal report, presentation to senior management, or a journal article that now requires high quality hard copy.

Media flexibility is also important in selecting a device. Some color hard copy devices can print on different types or sizes of media. Plotters, thermal transfer printers, electrostatic printers, and ink jet printers can produce color transparencies. Plotters can also work with polyester film or vellum. Buyers often overlook these capabilities and fail to include those applications in their needs analysis.

Taking these issues into account and going over the graphics job list should give buyers a better feeling for their needs. Then users/buyers should find software to meet their needs. For some users an integrated package which offers graphics and other features may be more appropriate than a pure graphics package. For example, people dealing with large amounts of data may prefer a database/graphics package to manipulate their data and then transform it into patterns that can be seen.

After identifying their needs and selecting software, buyers should focus on choosing a color hard copy device. Although individual needs will vary, some rough starting points are:

<table>
<thead>
<tr>
<th>Business/ Technical/ Graphic Arts/ Production</th>
<th>Colors Needed</th>
<th>Resolution (dots/in.)</th>
<th>Quality Needed</th>
<th>Throughput</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphtics</td>
<td>4-8</td>
<td>150 - 400 - 500</td>
<td>varies</td>
<td>higher speed</td>
<td>lower cost</td>
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<td>Graphtics</td>
<td>4-8</td>
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<td>varies</td>
<td>higher speed</td>
<td>lower cost</td>
</tr>
<tr>
<td>Graphtics</td>
<td>full color</td>
<td></td>
<td>high quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphtics</td>
<td>plus shading range</td>
<td></td>
<td>only</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graphtics</td>
<td></td>
<td></td>
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</table>

After determining the level of quality needed, buyers need to determine which devices can produce that type of output. To understand the quality differences between color hard copy devices, the buyer should understand the difference between vector and raster...
technology.

Line quality resolution depends on whether raster or vector technology is employed. Figure 3 shows the difference between lines drawn on raster and vector devices. Simple definitions of the two techniques are:

Raster Device: Output is an array of dots. Resolution is determined by the size of the dots, the accuracy of dot placement, and the number of dots per inch. A line would be a ray of dots.

Vector Device: Creates lines by drawing between two end points. Resolution is determined by how closely the device can hit the two end points, how small of a move between two points can be programatically drawn (addressable resolution), and how small of a distance between two points can be mechanically drawn (mechanical resolution).

Line quality in a raster device depends on the angle of the line. Horizontal and vertical lines will appear smooth. However, angled lines will have jagged edges due to the dot placement needed to form the line. Manufacturers can improve line smoothness by increasing the size of the dots, increasing the number of dots per inch, or increasing the accuracy of dot placement. Increasing the dot size results in wider lines. Increasing the number of dots per inch may result in longer times to process an image. Increasing the accuracy of dot placement will increase the cost of the device.

Line quality in vector devices depends on the combination of addressable and mechanical resolution. When a plotter draws a line between points A and B it is actually drawing to the points on a grid between A and B. Figure 4 shows how a vector line is drawn. The spacing between the grid points corresponds to the mechanical resolution. Different levels of resolution become apparent when vector devices draw circles and parallel lines. At lower resolutions, circles may not be entirely closed or parallel lines may not appear parallel. Mechanical resolution is more difficult to control and devices with higher mechanical resolution will be more expensive.

All printers are raster devices because they create images with a series of dots. Plotters are vector devices. Film recorders can be raster or vector devices. Vector color hard copy devices will produce high quality line graphics. Whereas raster devices will produce complex images and shapes better than a vector device. Since quality is an individual judgment, the best solution is to simply compare actual color output from the different devices and recognize the constraints of each technology.

Cost is another important issue. By failing to recognize many high value intangible benefits of owning a color hard copy device, buyers underestimate the return on their investment. In the long run, buying a color hard copy device will be less expensive than going to an outside graphic art agency. Some non-tangible benefits that are often missing from a cost justification are:

- Improved security. Since the graphics don't go to an outside vendor, security is better because the graphics never leave the business site.
- Meeting time constraints. Data can be charted immediately. There are no delays while the data is at an outside agency. Owning the color hard copy device also makes last minute revisions possible.
- Improved presentations. Color hard copy increases credibility and persuasiveness.
- Increases the value of databases because trends among the data become more visible.

As a buyer goes through the purchase decision there seems to be as many factors to consider as there are hardware and software vendors. To simplify the process we have created "Ten Steps to Choosing the Right Color Hard Copy Device." Figure 5 lists these steps which can serve as a check list during the purchase decision.

Some of the key issues for people using SAS/GRAPH software are:

- Plotter vs Printer: Some of the most popular applications involving SAS/GRAPH software are charts/graphs, and tables merged with charts/graphs. For high quality line graphics a pen plotter offers the best results at a reasonable price. If your hardcopy is dominated by text then a printer will provide faster throughput, but it will cost two to three times as much as a plotter for comparable line graphics quality.

- Printer Trade-offs: Ink jet and thermal transfer printers offer the best combination of color quality and price for color printers. An ink jet printer will produce transparencies with brighter color than a thermal transfer printer. An ink jet printer will produce strictly text, color hardcopy faster than a thermal transfer printer. Most thermal transfer printers have relatively slow text speeds, but their hardware is very simple and reliable. Thermal transfer printers may produce mixed text and graphics faster than an ink jet printer depending on the complexity of the graphics. Both ink jet and thermal transfer printers require special paper. Laser printers and electro-static printers cannot provide high quality color hardcopy at a reasonable price. Although dot matrix printers are inexpensive, their color hardcopy is not presentation quality and they are noisy.

- Shared Resource Configurations: The device will need to automatically feed paper (roll or sheet paper) and run unattended. Can the device also automatically feed transparencies? What throughput is the device capable of?

- What resolution is needed for professional looking hardcopy? Quality is an individual judgment. However, 300 dots/inch is considered letter quality text. High-end laser printers will offer 600 dots/inch B&W hardcopy. 180 Dots/inch is considered "near letter quality." A printer will have to approach 1000 dots/inch to match the line graphics of a plotter. Some raster devices offer higher resolution (dots/inch) on the vertical axis. Since
most letter strokes are vertical, increasing the vertical resolution provides better looking text.

- What is considered a fast plotter: Plotter throughput is influenced by the type of graphic. For hardcopy with a lot of area fill, pen speed is important. Pen speeds around 30 inches/sec. are considered fast. For graphics with a lot of line drawing (characters and short line strokes), acceleration is important to quickly get the pen up to full speed. Average plotters have pen accelerations around 2-4 g's. Fast plotters have pen acceleration of 6 g's.

- Which devices print on transparencies: plotters, ink jet printers, thermal transfer printers, laser printers (B&W), electrostatic printers.

- Are any particular devices better than others for maps: Maps are primarily complex line strokes with large filled in areas. A plotter provides high quality line strokes, but large amounts of solid fill will slow throughput. Color printers will produce areas of solid fill faster, but their line strokes (eg. regional boundaries) will show jagged edges.

- Are any particular devices better than others for Gantt charts: Gantt charts are primarily vertical and horizontal lines with text. Although pen plotters provide the best line graphics, a raster device will provide quality gantt charts. Horizontal and vertical lines minimize the jagged edge effect in raster device lines. A raster device will produce gantt charts with fairly smooth lines and will print the text faster than a plotter.

- Can you attach an asynchronous ASCII device (plotter) to a synchronous EBCDIC device (IBM mainframe): Protocol converters let you connect ASCII devices to EBCDIC devices. There are two types of protocol converters; printer emulators and cluster controllers. Printer emulators are less expensive than cluster controllers, but you need one printer emulator for each ASCII device/plotter you connect to the system. Cluster controllers are more expensive, but you can connect several ASCII peripherals to it. Many EBCDIC/IBM environments may already have a cluster controller on the system to support their ASCII terminals. In this situation, an ASCII device/plotter can be attached between the system and the terminal in eavesdrop mode.

CONCLUSION

There is a wide variety of color hardcopy devices available today. Different technologies offer different advantages and disadvantages. Choosing the right color hard copy device is one of the keys to an effective graphics system. Using this guide will give you a better understanding of your needs and the potential color hard copy solutions.

<table>
<thead>
<tr>
<th>Technology</th>
<th>Features</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dot Matrix</td>
<td>1-8 colors, 3 min. per print, low to medium quality</td>
<td>proven technology, low cost, reliability</td>
<td>poor color quality, no control of color brightness, noisy</td>
</tr>
<tr>
<td>Pen Plotter</td>
<td>2-10 colors, 3-10 min. per print, high quality</td>
<td>variable media, high apparent resolution, low cost, reliability</td>
<td>speed/size, no control of color saturation or brightness</td>
</tr>
<tr>
<td>Ink Jet</td>
<td>unlimited color, 1-5 min. per print, med. to high quality</td>
<td>colors available, low cost, quiet, merge text with graphics</td>
<td>poor image durability, special paper needed</td>
</tr>
<tr>
<td>Thermal Transfer</td>
<td>unlimited color, 1-2 min. per print, med. to high quality</td>
<td>reliability, low cost, quiet, merge text with graphics</td>
<td>high cost of supplies, difficult to control color brightness, special paper needed</td>
</tr>
<tr>
<td>Film Recorder</td>
<td>unlimited color, 2 min. to high quality</td>
<td>very high image and color quality, reliability</td>
<td>high cost of supplies, long turnaround times to develop film</td>
</tr>
<tr>
<td>Electro-Static</td>
<td>unlimited high throughput</td>
<td>high cost, primarily B&amp;W devices, not useful for low volume runs, complex hardware, uncertain color quality</td>
<td>high cost, primarily B&amp;W devices, not useful for low volume runs, complex hardware, uncertain color quality</td>
</tr>
<tr>
<td>Electro-Photographic</td>
<td>high throughput, med. to high quality</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magnetic Laser</td>
<td>quality cost/copy</td>
<td></td>
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</tr>
</tbody>
</table>

Figure 1
Color Hard Copy Devices

Figure 2
Questions for Needs Analysis

- Will graphics be a primary or secondary use of the computer system?
- How many people will be producing graphics?
- What is your budget?
- Will your long-term needs for color hard copy significantly increase from your present needs?
- What output media (paper, transparencies, polyester film, vellum) seem most appropriate for the jobs on your list?
- What size media will you need?
- What level of quality do you consider acceptable for the jobs on your list?
- Do you often have a need to merge text and graphics on the same page?
- Will your jobs require that many copies be produced in a short time?
- Is it important that final copies can be produced without an operator present?
- What kind of training will you need?

Figure 3

**RASTER**

90°

45°

**VECTOR**

9°

14°

Figure 4

*Mechanical same as Addressable (both = 0.001")*

- Overhead Presentations: Look for devices that draw on transparencies.
- Publication-quality
- Large Charts: Draw on different size media.

Figure 5

Ten Steps to Choosing the Right Color Hard Copy Device

1. Consider the computer system the device will be working in.
   - Mainframe vs Micro: Some devices adequate for a PC may not be able to handle the workload of a mainframe system.
   - Multi vs Single User: Some devices require more attention than others to operate. In a shared environment look for features such as automatic paper advance or sheet feed.
   - Interfaces Available: Are the devices compatible with your computer system(s)?

2. Choose software that meets your needs.
   - An integrated package offering other functions may be more appropriate than strictly graphics software.

3. Check to see which devices are supported on the software you have chosen on your computer system.
   - Make sure you have several choices so that your software will not lock you into a device that you don’t want.

4. Determine your present and future needs.
   - High vs Low Volume: High volume will require several devices or one shared resource.
   - Ability to expand or upgrade?

5. Determine budget parameters
   - Purchase Price: A wide price range is available for color hard copy devices, look only in your target range to avoid wasting time.
   - Cost of Ownership: Total cost also includes operating costs, supplies costs (Is special paper needed? How long will the pens last?), and service costs (repair costs, downtime costs).

6. What type of hard copy is needed?
   - Overhead Presentations: Look for devices that draw on transparencies.
   - Publication-quality
   - Large Charts: Draw on different size media.

7. Compare output between devices.
   - The choice of quality is an individual judgment. Compare actual hard copy from different devices. Try producing the same test graphic on the different devices.

8. Watch the devices operate.
   - Are they noisy? (Will it matter?)
   - Is one faster than another?

9. Check ease of use.
   - Is it easy to load the media, ink, ribbon, or pens?
   - What special features are available: auto pen capping, different interfaces.
   - Good Documentation: Is it easy to read/understand?
10. Look for proven reliability.
- Check the reputation of the device's manufacturer by talking to MIS personnel, dealers, and sales reps.
- Check the company's reputation for post-sale service and support (Does the company have a support phone number?)

ACKNOWLEDGEMENTS

I would like to thank all the people at Hewlett-Packard San Diego Division who gave me their comments and suggestions. Your help and guidance greatly improved this paper.

BIBLIOGRAPHY


SAS/GRAPH is a registered trademark of SAS Institute, Inc., Cary, NC, USA.

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