APPENDIX IV.3

A SURVEY OF COLOR VIDEO FRAME BUFFER DISPLAY SYSTEMS FOR DESIGN GRAPHICS RESEARCH

This appendix presents the results of a comprehensive color display system survey conducted at the General Electric Corporate Research and Development Center during 1980. The information contained in the survey report should be highly useful in selecting a display configuration for a sensor prediction techniques research system. It should be noted however, that this survey was conducted for purposes of serving specific needs by a specific General Electric organization in the area of design graphics research. Hence, much of the author's commentary is given in that context.

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SUMMARY

The purpose of this survey is to investigate the frame buffer marketplace as it is today and project near future developments in order to recommend a suitable replacement for the DeAnza 2000 series system presently in use. Video frame buffer technology has been very dynamic in recent years resulting in some very powerful systems being offered at dramatic cost reductions.

After studying the requirements for design graphics research, the following criteria were established to restrict the survey to those vendors that would successfully satisfy these requirements:

- Refresh color video display type system
- Minimum of 512 × 512 pixel resolution
- Minimum of 8 bits memory per pixel
- Minimum of 5 bits per color gun in the color map
- Workable interface to PDP-11 and VAX computers

In terms of design graphics requirements, the real differences in cost among the viable systems seem to vary directly with the sophistication of the related processor. Some information on available hard copy units, video disks, and NTSC encoders is also included in this report.

KEY WORDS

computer graphics, color video display, image processing frame buffer, design graphics

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A SURVEY OF COLOR VIDEO FRAME BUFFER DISPLAY SYSTEMS FOR DESIGN GRAPHICS RESEARCH

P.R. Atherton

INTRODUCTION

The Design Graphics Program, which is part of the Information Technology Branch of the Automation and Control Laboratory at General Electric Corporate Research and Development, has been working with a DeAnza 2000 series color video frame buffer system for over a year. Image displays have consisted mostly of output from SynthaVision* and MOVIE.BYU† imagery for various applications primarily oriented toward CAD/CAM development. Recently, some new and very exciting frame buffer systems have been developed by various vendors and are being offered at excellent price/performance ratios. With the appearance of these new powerful higher resolution systems, it was deemed necessary that Design Graphics should update their system to provide a more suitable environment for color video computer graphics development.

The color video frame buffer marketplace is a very dynamic environment which has made information gathering a difficult task in that various sources will often have different responses, and what is said today may be obsolete tomorrow. The author of this report welcomes any questions, comments, or added information pertaining to color video frame buffer systems, especially from those people who have had experience on any of the related systems.

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*SynthaVision is a three-dimensional modeling system developed by the Mathematical Applications Group, Inc. (MAGI) of Elmsford, NY.

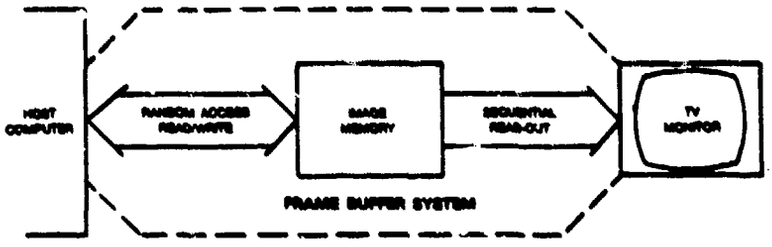
†MOVIE.BYU is a polygonal display program primarily used for movie animation developed in the Civil Engineering Department at Brigham Young University in Provo, Utah.

Manuscript received February 12, 1980

VIDEO FRAME BUFFER DISPLAY SYSTEMS FOR DESIGN GRAPHICS RESEARCH

Definition:

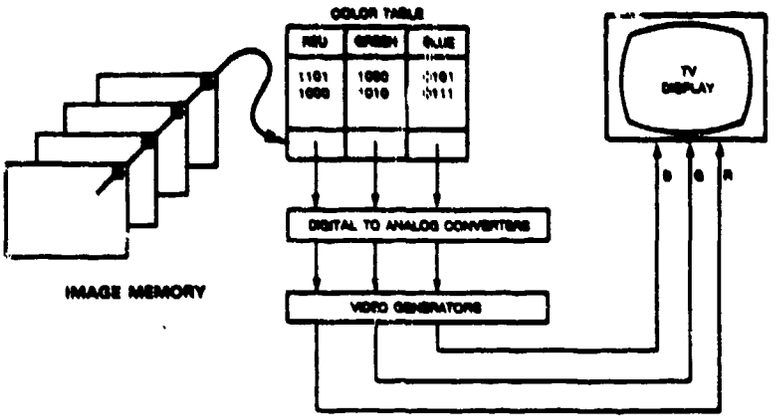
A video frame buffer system is basically a video raster scan display driver centered around a large piece of memory which contains image information.



The frame buffer system allows the user to update and read back from the image memory, while at the same time, the entire digital image information is sequentially read-out and converted to analog video signals for display on a TV monitor at refresh rates (from 20 to 60 times per second).

IMAGE MEMORY AND COLOR MAP ORGANIZATION

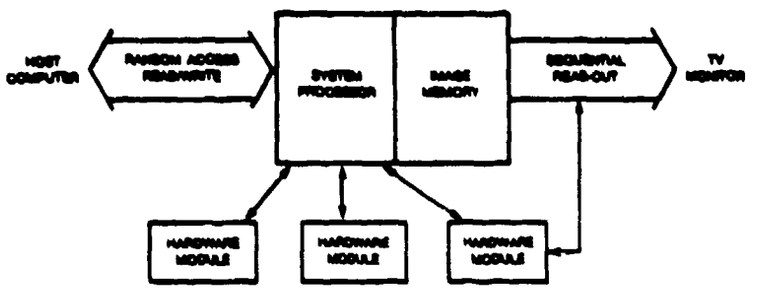
For most of the systems discussed in this survey, the image memory structure is essentially the same. A modular section of memory is dedicated to an entire display, such that one bit of information corresponds to a single pixel location on the screen. The number of memory modules corresponds to the number of bits of information dedicated to each individual pixel. The pixel bit information describes an address in a color map table.



The color table consists of a list of intensity values. Each location in the table contains relative intensities for each red, green, and blue color gun. During the sequential pixel scan-out (read), these values are taken from the table in the order that the image memory dictates, converted to analog signals then to video for display. The whole image memory is read out, converted, and displayed during a single refresh. There are some variations and enhancements to this basic design which will be noted in the system descriptions.

SYSTEM PROCESSORS

Many frame buffer systems utilize micro- and/or array-processors to handle commands passed down from the host and to speed up the execution of various graphics operations. The processor normally sits between the image memory and the host computer with access to various special purpose hardware modules.



The system processor will accept commands from the host computer, translate them, and perform the appropriate operations to the image memory. These tasks may range in complexity from simply writing a pixel to enhancing all the visible edges in a digitized photograph. To speed up the execution of some of these processes, many vendors have provided special purpose hardware modules. A prime example of a hardware module useful for Design Graphics is the vector generator. Some vector generators are capable of rendering vectors on a color video display at rates of up to 16,000 vectors per second.

Many of the system processors can also be user programmable in micro-code. User programmability may prove to be a nice feature for Design Graphics in that it may allow us to put in the processor capabilities to do such things as fast parametric surface rendering — an operation no vendor offers today.

System processors can become very big and powerful and that power is usually reflected in the cost of the frame buffer system. In this survey, a lot of discussion will be devoted to the system hardware, firmware, and software facilities. In most cases, firmware and hardware facilities will reflect the power of the system processor and related hardware modules, while software facilities will describe code that exists on a host computer and is often FORTRAN callable. User programmability will describe capabilities for the user to down load or directly program the system processor.

DESIGN GRAPHICS CONSIDERATIONS

The requirements for a video frame buffer system for the Design Graphics Program range from basic scan-line displays and interactive operations to sophisticated surface imagery and enhancement procedures. Some of the considerations include:

1. 2D and 3D model space control
   - Viewport
   - Window
   - Rotation
   - Translation
   - Scaling
2. Display of design and manufacturing models
   - Wire frame drawings
   - Sculptured surfaces
   - Complex solids
   - Finite element results
   - Text generation and control
3. Capabilities for various image generation techniques
   - Pixel by pixel
   - Scan-line via run-length encoding
   - Polygon and area fill
4. Ease of program development and implementation
   - FORTRAN callable software
   - High level graphics language
   - SIGGRAPH CORE graphics standard
5. Speed and ease of user interaction
   - Hardware or firmware facilities (i.e., zoom, scroll, or vector generation)
   - Peripheral devices (i.e., tablet, light pen or trackball)
6. Animation capabilities (i.e., cutter path or assembly visualization)
   - Run-length decode facilities
   - Image memory and color map controls
   - Video disk facilities
7. Image enhancement capabilities
   - Edge detection
   - Anti-aliasing
   - Contrast enhancement
   - Hue, intensity, and brightness controls

8. Transportation of image displays outside of laboratory area
   - Direct hard copy
   - Polaroid or 35 mm
   - Video recorder
   - Video disk

PRELIMINARY DESIGN GRAPHICS REQUIREMENTS

The foremost consideration involved in the selection of a video frame buffer system is the capability of displaying the desirable images (SynthaVision, MOVIE.BYU, Sculptured Surfaces, etc.) in a more effective manner than the existing DeAnza ID2000 series system. The most obvious improvement would be the increase in image resolution from 256 × 256 (medium resolution) to 512 × 512 (high resolution) or to 1024 × 1024 (ultra-high resolution). Another improvement that could significantly enhance image display is the increase of the color table depth to allow for a greater variation of intensities over the range of a specific hue. In particular, changes across a curving surface would appear much smoother, and the effectivity of various lighting, texture, edge-smoothing, and anti-aliasing models would be greatly enhanced.

To restrict the survey to those vendors that could successfully fulfill our needs, preliminary requirements for selecting a video frame buffer display system are described:

1. A refresh display system to allow continual visual feedback of image updates.
2. A workable interface to the PDP11/70 and VAX computers.
3. Minimum of 512 × 512 pixel resolution.
4. Minimum of 8 bits of information per pixel, thus allowing 256 colors to be displayed simultaneously.
5. Minimum of 5 bits per color gun in the color map.

Note that this survey does contain some systems that do not satisfy requirement 5. These systems were included for completeness in that some people might choose to live with the 4 bits of color intensity if the system is extremely successful in regard to other Design Graphics considerations.

SYSTEM CATEGORIZATION

In terms of Design Graphics requirements *versus* system design *versus* price criteria there seem to be 4 basic types of frame buffer systems available.

1. High resolution (512 × 512)
2. Ultra-high resolution (1024 × 1024)
3. High resolution upgradable (modular) to ultra-high resolution
4. Image processing systems for both high and ultra-high resolutions

In some cases, there is difficulty in discerning the image processing systems (4) from the image display systems (1, 2, and 3) since some systems try to bridge that gap to entice both markets. However, this is to our advantage in that the Design Graphics considerations previously discussed do reflect a need for some image processing capabilities such as edge detection and anti-aliasing. Therefore, I have classified as image processing only those systems for which a high price would be paid for powerful facilities that would do little to satisfy our needs.

A major point of contention pertains to the high *versus* ultra-high resolution decision. After some market study, it appears that the ultra-high resolution systems are not quite ready for consumption. Most vendors believe that the ultra-high resolution systems will not really be effective until the 64k chips become readily used. The significance of this probably will not be felt in the frame buffer market for about 2 or 3 years. Many hardware and firmware facilties offered with the high resolution systems simply are not available with ultra-high resolution. Peripherals, particularly video recording hardware, simply does not exist for 1024 × 1024 displays. Finally, software that was developed for high-resolution pixel data executes much slower and often demands more host memory on ultra-high resolution systems. On the other hand, the high resolution systems offer a very cost effective solution in that it is the same resolution of standard television. Thus, most of the video equipment related to the system has been in use for years and is greatly refined. It is also relatively less expensive. The high resolution frame buffer systems have also been in use for many years so that there are now many viable vendors who are operating in a very competitive marketplace. All these considerations make it pretty apparent that we should be directing ourselves toward the high resolution systems while keeping a close eye on the ultra-high resolution market developments.

VENDOR SURVEY

This initial survey was specifically designed to obtain the general system configurations and capabilities in order to determine what types of systems satisfy our needs, to what extent, and at what cost. A number of decisions have already been made regarding the minimal requirements and the high *versus* ultra-high resolution question. We can now cut through a lot of extraneous information and concentrate on the system configurations that really concern Design Graphics.

For each system, pertinent information has been extracted and entered on a form sheet which can be found in Appendix A. Following each form sheet is a system diagram produced by the vendor (if one was available). Note that all technical and cost information has been based on high resolution (512 × 512) systems. The basic system cost refers to a simple system containing:

- 512 × 512 Image memory with at least 8 bits depth at each pixel
- System processor
- Interface to host computer (PDP 11/70)
- 19-Inch color monitor ($4000 if not offered directly)

Added to the basic system cost are the optional peripherals and facilities that would help satisfy our needs resulting in a total system cost.

The table following this section is an attempt to squeeze the tables from Appendix A onto a single sheet of paper to give the reader a *very* generalized overview of the systems surveyed. Some of the things to look for are:

Approximate Total Price: How much system power is needed in relation to the time of next foreseeable purchase?

Memory Configuration: Modular bit planes (512 × 512 × 1) are preferred to allow a more flexible initial purchase with easy lower cost upgrading later. Remember the 8 bits depth per pixel requirement (no. 4, page 7) mentioned earlier.

Pixel Access: The time required to read or write a pixel is very important in user interaction and critical for repeated operations.

Color Map: The greater the number of intensities allowed per Red-Green-Blue color gun, the smoother a color change can be made. Note the 5 bits per color gun requirement (no. 5, page 7). Also, the longer the color map (the number in parenthesis), the greater the number of colors that can be displayed on the screen for a single image if the corresponding number of bits per pixel are provided.

Programmable Processor: May allow the user to do specialized fast processing of image generation.

Host Interface: Look for DMA, because extended memory configurations could cause troubles going to the VAX or other host computer. Also, extended memory systems that work on other PDP 11s are more difficult to implement on the 11/70.

Desirable Facilities: Purely a personal reaction to the hardware, firmware, and software facilities a system has to offer. The reader should consider the requirements, examine Appendix A, and establish his own reaction about the desirable/offered facilities

1024 × 1024 Display Upgrade: If there is a strong near-term desire to display images at ultra-high resolution, even for just test purposes, we should definitely value this category as a very high priority item. If we want to hold off for 2 to 3 years until more viable systems are available, this factor can be considered in very low priority.

VIDEO FRAME BUFFER SYSTEMS (TABLE BRIEF)

	Approximate Price	Memory Configuration	Pixel Access	Color Map	Programmable Processor	Host(PDP-11) Interface	Desirable Facilities	1024 x 1024 Display Upgrade
DeAnza ID5000	$19,525	Restricted 8 or 12	1.8 Ms	4-4-4 (1024)	No	DMA Unibus	Weak	N/A
AED 512	$19,820	Modular 8 Max	1.0 Ms	8-8-8 (256)	No	DMA Unibus	Good	N/A
3 Rivers CVD	$20,000	RLE Format		5-5-5 (64)	No	Extended Memory	Weak	N/A
Grinell GMR-27	$22,000	Modular 32 Max	1.5 Ms	8-8-8 (1024)	No	DMA DR11-B	Weak	Rough
Grinell GMR-270	$23,200	Modular 32 Max	1.5 Ms	8-8-8 (3-256)	No	DMA DR11-B	Weak	Rough
ADI Light-50	$23,300	Modular 16 Max	1.2 Ms	5-6-5 (256)	Yes-download TMS9900	DMA like DR11-B	Good	N/A
Lexidata 3400	$25,800	Modular 16 Max	1.0 Ms	8-8-8 (256)	Difficult	DMA Unibus	Good	Trade-in
Genisco GCT-3000	$31,050	Modular 14 Max	1.5 Ms	8-8-8 (256)	Yes 2k RAM 6CT 3011	DMA Unibus	Good	Fair
DeAnza VC 5000	$34,950	Restricted 16 only	1.2 Ms	4-4-4 (1024)	Yes LSI-11	DMA via high speedport	Weak	Very Rough
Aydin 5216	$42,500	Modular 16 Max	1.0 Ms	8-8-8 (256)	1 Mega Word Intel 8086 (Forth)	DMA DR11-B	Excellent	Fair
Norpak VDP	$44,000	Modular 32 Max	1.5 Ms	8-8-8 (256)	Yes-download Bit-Slice Micro	DMA DR11-B	Very Good	N/A
DeAnza IP 5000	$48,000	Restricted 24 only	800 Ns	8-8-8 (3-256)	User Programmable Pipeline Array Proc.	Extended Memory	Fair	N/A
Ikonas	$48,000	Modular Max 40	400 Ns	8-8-8 (1024)	Fast 32 bit Micro	DMA DR11-B	Very Good (excellent Pass)	Built-in
Ramtek 9400	$53,100	Modular 16 Max	1.12 Ms	8-8-8 (1024)	Not Recommended Z-80	DMA DR11-B	Excellent	Rough
Comtal Vision One/20	$40K to $700K	Modular Max 512	1.5 Ms	8-8-8	LSI Micro	DMA DR11-B	Good	Rough

BRIEF SYSTEM COMMENTARIES

This section contains a commentary on each video frame buffer system in which I will try to enphasize the strong and weak points of each system *relative to the needs of Design Graphics*.

DeAnza ID5000 is the big brother of the DeAnza 2000 now in use. Relative to the other newer systems in this survey, most commentaries must be directed to the system's shortcomings which include:

- Limited memory configurations
- Restricted and slower memory access
- Only 4 bits of intensity per RGB in the color table
- Very limited facilities

The only real positive thing about the DeAnza ID5000 is its low price.

AED 512 was one of the big stars of the SIGGRAPH '79 vendor exposition. It can act as a reasonably powerful pixel addressable frame buffer display system, or as a sophisticated character oriented graphics terminal and also comes with a Tektronix emulator. In terms of price versus performance, the AED 512 is very hard to beat in the lower price range of this survey. The only limitations (within the lower price range) that I see are the maximum of 8 bits depth per pixel.

Three Rivers CVD is basically designed for the play back of animation sequences. The major limitation of its Run-Length-Encoded (RLE) based memory is that many color variations across a single scan line cannot be executed. Smooth surface imagery generated by SynthaVision or sculptured surfaces would have to be approximated resulting in low quality imagery. The CVD does not even attempt to utilize most of the facilities we need and can only display 64 colors at one time (equivalent to 6 bits of depth per pixel).

Grinell GMR27 is a pretty good low cost image display type of frame buffer including a 1024 long color map. However, the GMR27 lacks the facilities of some newer comparable systems.

Grinell GMR270 is the image processing version of the GMR27. Basically, we would be paying more for the GMR270 than the GMR27 for image processing facilities that we have little use for.

ADI Light-50 is a newcomer to the frame buffer marketplace but it appears to be quite viable and it is the only system that includes a NTSC encoder. The RGB intensity control in the color map is somewhat limited and memory planes can only be acquired in 512 × 512 × 4 units. However, the system does provide a way for the user to down load micro code to the TMS 9900. At this point in time, the ADI Light-50 has not yet been tested as a consumer product since most recent efforts have involved software interfacing with CHILD, Inc.

Lexidata 3400 is a very flexible modular system that offers some nice facilities in a pretty comfortable price range. Some of the options include:

- Integer zoom controller
- Multiple scroll controllers

- 1024 Long color table with 8 bits per RGB
- Real-time edge smoother for 2X and 4X zoom
- Multiple overlays

Genisco GCT-3000 does offer some good facilities at a fairly reasonable price. However, aside from the Grafpac II software package, the system offers little more than the AED 512 which costs almost half as much; and the GCT-3000 cannot compete with some of the higher price systems in terms of processor power. Considering this middle-market price/performance position Genisco has taken along with rumors of hardware unreliability, it would be more judicious for Design Graphics to avoid the GCT-3000.

DeAnza VCS000 looks like an attempt to move away from the norm of frame buffer system design . . . but not in our direction. The user has to buy a 512 × 512 × 16 image memory configuration and at the same time be limited to only 4 bits of intensity per RGB color gun. There is a reasonable vector generator and character controller, but little else in the way of facilities . . . and a relatively high price tag.

Aydin 5216 is the system to beat in terms of hardware, firmware and software facilities which include 3D object transformations and Z-sort hidden surface removal. The system even offers a user programmable Intel 8086 with one Megaword of memory and the Forth programming language. There is a very long (2048) color map, and with an extra video card (costing about $3000) can offer 8 bits depth of intensity per color gun as a non-standard configuration. However, at this point in time, the software packages are not yet complete.

Norpak VDP is a Canadian company that is new to the high level frame buffer market. They offer many nice features but it seemed as though every time I wanted to get some detail, I got a response like "well . . . its not quite complete yet." For that kind of money I'd want to see it completed and tested before buying.

DeAnza IP5000 is good image processing system at a reasonable price, but really quite overpriced for Design Graphics use.

Ikonas is probably the best frame buffer system on the market to do computer graphics image display research on. The possibilities for their 32 bit microprocessor along with some of the built-in hardware facilities are really quite interesting. Ikonas claims to have developed a system that is modular enough to keep them on top of the research graphics market for at least the next few years. Engineers from other frame buffer companies say to look for good things in the near future from Ikonas.

Ramtek 9400 probably has the best vector generator in the market (although Aydin's untested hardware shows promise). It also offers some other nice facilities like 2D rotation, entity detection and down load list processing. For an additional $6100 of hardware they will also offer 8 bits of color depth intensity per RGB which is non-standard.

Comtal Vision One/20 is the top of the line for image processing systems. They offer a real-time pan of a 4096 × 4096 × 8 bit image and a movie capability to viewing a 512 × 512 × 512 bit array. It is basically a very powerful high priced system to perform operations we do not really need.

RECOMMENDED SYSTEMS

In terms of price/performance criteria, I see six video frame buffer systems that stand out from the others. In order of approximate price they are:

AED 512	$19,820
ADI Light-50	$23,200
Lexidata 3400	$25,800
Aydin 5216	$42,500
Ikonas	$48,000
Ramtek	$53,100

The six systems seem to fall into two price ranges:

lower price range: $19,820 to $25,800

higher price range: $42,500 to $53,100

The lower price range systems are good, fast modular systems that will satisfy our needs quite nicely. The higher price systems are quite similar, except that they have much bigger processors, more hardware facilities and are upwards compatible to the ultra-high resolution displays.

In the higher price range, Aydin and Ramtek both provide the best hardware support modules, and extensive firmware/software facilities. Ramtek seems to offer a superior vector generator, but Aydin does support 3D object transformations and offers an easily programmable micro which could certainly prove valuable for surface generation. One the other hand, Ikonas provides a more state-of-the-art technology with the 32 bit 200 Nsec cycle processor with fast hardware multiplier and various special purpose hardware facilities including 3D transformations. Ikonas also has its image memory configured in such a way that an ultra-high resolution upgrade would only require a monitor change and setting a software switch. All other available systems require some hardware changes. So at the higher price range it comes down to a preference between Aydin's already developed facilities to Ikonas's more advanced engineering.

At the lower price range, the task of selecting a better system becomes more difficult. In my opinion, either the AED 512, ADI Light-50 or the Lexidata 3400 would be good selections that would stand us in good stead for the next two to three years. To help with this decision, I believe that we should look further into any special deals or company relationships that might provide more incentive one way or another. The following section will discuss a suggested approach to making the final selection.

THE NEXT STEP

I believe the next logical step would be to evaluate our present needs and place into perspective our near term goals and our long term goals. Using that criteria, we should determine whether we need to put down the money for a high powered system, or whether we can satisfactorily pursue our goals with a lower cost system. In either case, the following questions should be asked of each critical vendor and responses requested in writing along with a formal detailed quote:

1. What is the delivery lead time?
2. What are the levels and costs of factory and field service?
3. What is the actual mechanical packaging (i.e., parts supplied)?
4. Are there any special company relationships to consider?
5. Are there any special price cuts to consider?
6. What are the planned future capabilities and to what extent or cost will they be available to us?

The responses to these questions may well provide the thrust to select one vendor over another. For example, Genigraphics received a handsome discount from Lexidata with the intent of future quantity buying. Some of the vendors suggested a company contract that would allow us to utilize their software packages on many in-house systems for one set price. Ikonas, for one, has stated that it is virtually impossible to deliver a system before 1980. We must understand all these factors, evaluate them, and then compare the trade-offs in order to make a final selection.

OTHER HARDWARE TO CONSIDER

There are some other devices related to video frame buffer systems that may help satisfy some of our requirements. They all represent ways by which we may record our images for communication or special applications.

NTSC Encoders

The purpose of an NTSC encoder is to transform the RGB video signals that are displayed on high quality monitors, to standard television signals so we may record imagery directly. I found only two encoders that sold for under $3000.

Lenco Inc. offers NTSC encoder that "was specifically designed to encode high resolution color graphic computer displays irregardless of scan rates." They do claim that it will encode 1024 × 1024 resolution displays. Cost: $1595

Video Modular Systems offers an NTSC encoder that does not presently handle 1024 × 1024 resolution displays, but they suggest that they will have that capability in 2 to 3 months. Cost: $940

Video Disks

A video disk is a disk unit especially designed to store and play back video images. It is presently being used quite successfully for computer animation in that it allows the storing of images at a slow rate and will play them back at a real-time rate. This allows for a much more flexible recording system than the traditional movie frame-by-frame photography method because there is no wait for film processing, and also because the animator may selectively edit random frames. The major problem with video disks is that most of them use laser technology making them quite expensive. A price tag above $100,000 is not unusual for a good digital system. However, there are some alternatives.

Oktal offers an analog video disk system for $40,000 which is being used in various places including Cornell's lab for Computer Graphics. As I understand it, the analog nature of Oktal's system requires so much tweeking that a video engineer should be on hand most of the time.

Eigen Video recently announced a lower quality low cost solution in the form of a magnetic disk. The monochrome recorder costs about $16,000, and the additional time base corrector for color recording boosts that system's cost to $24,500. The Eigen system can record up to 300 frames which is good for about 10 seconds of animation. The magnetic cassettes last approximately 100 hours before they must be rebuilt at a cost of $10 each.

The GE television development group in Portsmouth is looking into video disks and are planning on buying one already developed elsewhere. If animation is a definite requirement, I would recommend finding it at a system level because the costs of video disks are so high.

Some frame buffer systems now or soon will offer disk controllers in combination with hardware run-length decoders which may well satisfy most play back animation speed requirements. A lower cost solution would be the Three Rivers' CVD frame buffer system which is especially built for animation (discussed earlier in this survey). It could be purchased as a second frame buffer for $15,000 and used totally for animation display.

Hard Copy

At this point in time, color video hard copies are hard to find in a reasonable price range relative to their monochrome counterparts. The most notable systems available today are:

Trilog Inc. offers a system called COLORPLOT 100 which is based on a impact printer costing $9980. It produces a copy with 100 dots per inch vertical and horizontal resolution in about 3 minutes costing about 5¢.

Dunn Instruments has a hard copy unit that utilizes a Polaroid camera to make high quality 8 × 10 color photographs at about $5.00 per picture. The system will also allow for 35 mm slides to be taken and costs about $16,000.

Matrix Instruments produces a hard copy system very similar to the Dunn but with a basic system cost of about $12,800. It has the additional capability of formatting multiple images (2, 4, 6, 9, 25) on a single 8 × 10 Polaroid print which could result in substantial film cost savings. Unfortunately, each formatter costs $1000. Additional formatters are available for 35 mm slide (1-image-$3000) and microfiche (92 images-$1500). The total cost for a good system is about $20,000.

Xerox makes a color copier that will accept serial computer data and output a 100 dot per inch image. The system can also produce 35 mm slides and can operate in the normal copying format. Nice system for about $25,000.

Applicon now advertises an ink-jet plotter for about $40,000 that will make some nice color copies. Some examples of the ink-jet plotter output are on the wall in the Design Graphics Lab.

LOW-COST COLOR VIDEO DISPLAY SYSTEMS

At this point, I would like to note that some of the systems already mentioned may well satisfy the low-cost requirements while offering upward configuration possibilities in a modular fashion.

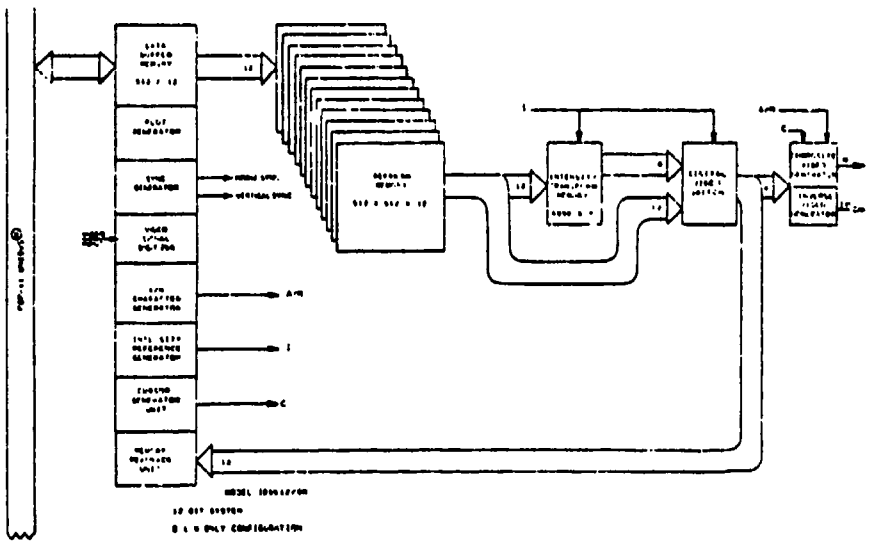
For example, Advanced Electronics Design, Inc. (AED) can configure a high resolution (512 x 512) system with 5 bits of depth at each pixel, PDP 11 interface, 14-inch color monitor, powerful firmware capabilities along with a Tektronix Plot-10 emulator for under $15,000 — not including quantity discounts. With 2 bits of depth, the cost is less than $12,500.

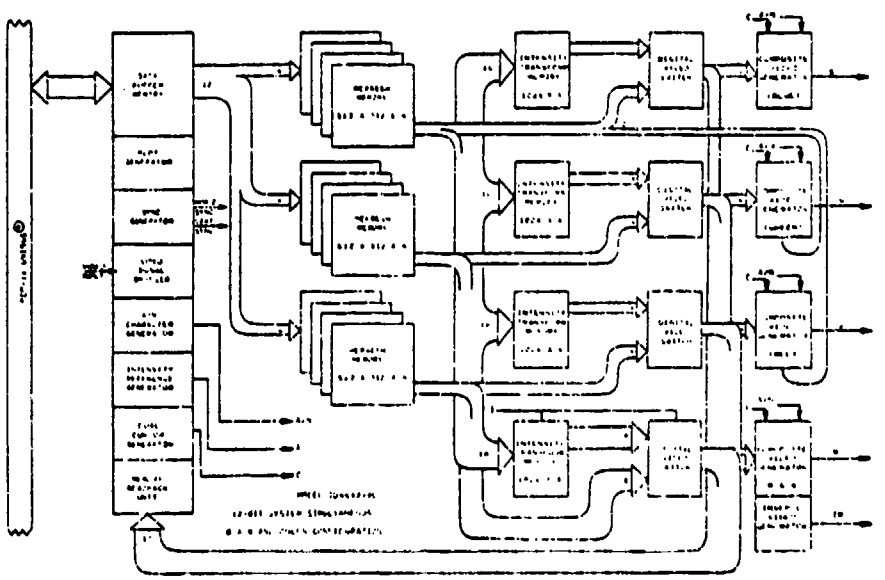
Applied Dynamics International (ADI) can put together a high resolution (512 x 512) system with 4 bits of depth at each pixel, PDP 11 interface, 14-inch color monitor, NTSC encoder, power firmware and a Tektronix emulator (Tek-Light) with some nice extensions for around $16,000.

These systems represent the upper-end of the low cost frame buffer spectrum, but they do offer some very nice features in a very cost effective manner.

Appendix A

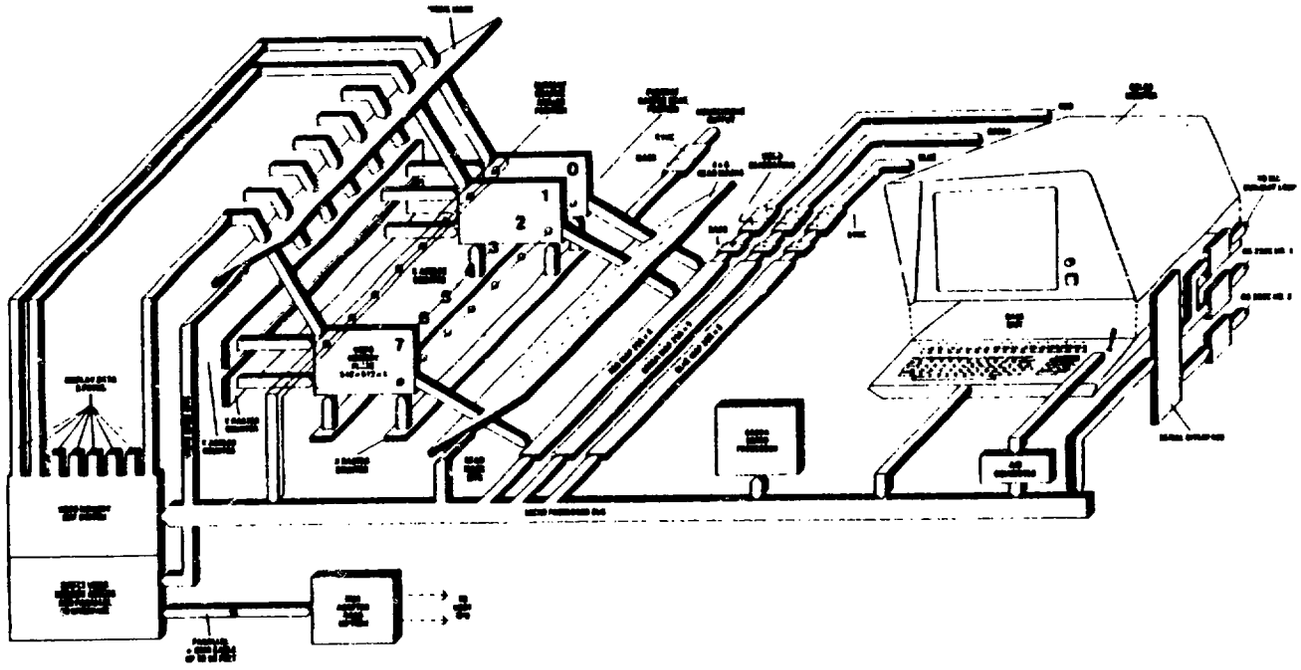
TABLES AND DIAGRAMS DESCRIBING COLOR VIDEO FRAME BUFFER DISPLAY SYSTEMS





SYSTEM DeAnza ID5000	**CONTACTS**	Rick Pizza Chuck Nordby San José, CA (408) 263-7155
IMAGE MEMORY **CONFIGURATIONS AND COSTS**	2 basic color systems 512 x 512 x 8 → color output 8 bits (3-R 3-G 2-B) 512 x 512 x 12 → color output 12 bits (4 each color)	
PROCESSOR (SEE ATTACHED)		
MEMORY ACCESS	**ONE PIXEL I/O AFTER INITIALIZATION** 1.2 Ms (average 1.8 Ms) Memory allocated line by line along DMA interface	
REFRESH RATE	30 Hz	
INTERLACE	2:1	
HOST	**PDP 11/70** "Standard PDP-11 Unibus interface" - Unibus registers	
INTERFACES	**VAX** VMS I/O Driver $650	or DMA Board -
PERIPHERALS	Joystick	$875
FACILITIES **H-HARDWARE** **F-FIRMWARE** **S-SOFTWARE** **U-USER/PROCESSOR**	H Color Table 256 x 12 (4 per gun) for 512 x 512 x 8 System 1024 x 12 (4 per gun) for 512 x 512 x 12 S VDLIB - Dec. 11 compatible $250 - Magnification function - real value - interpolated - Polygon fill - User interaction H Cursor H Alpha - Numeric Generator	
MONITORS		
NTSC ENCODER		
HARD COPY FACILITY	Recommend Dunn	
COST OF BASIC SYSTEM	512 x 512 x 12 System to allow 4 bits per RGB	~$18,500
DESIRED EXTRAS	VDLIB, Joystick	$19,525
TOTAL COST		
COMMENTS		

Advanced frame buffer architecture of the AED 512



SYSTEM AED 512	CONTACTS Gary Wilson (Sales) Bedford, Mass. (617) 275-6400	Pete Harris (Eng.) Sunnyvale, CA (408) 733-3555
IMAGE MEMORY CONFIGURATIONS AND COSTS	512 x 512 x 1 bit planes - Max. 8 (possible to hook up 3 sets of 8)	$885
PROCESSOR (SEE ATTACHED)	6502A Micro - not user programmable	
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION Line - 50 to 100 Ms initial - 30 Ms subsequent - 1 Ms RLE - 5 Ms per pixel	
REFRESH RATE	30 Hz	
INTERLACE	Yes	
HOST	PDP 11/70 DMA Unibus Interface	$2,000
INTERFACES	VAX	
PERIPHERALS	Keyboard with numeric pad and joystick (included)	

FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR		
	F	Included: Vector Generation - 9 Ms/pixel after initial Scroll Zoom 2x, 3x, 4x, 5x ... 16x Polygon fill - after vectors Area fill Run Length Encode and Decode Cursor - joystick control "Area of interest" - similar to window Circle generator
	H	Color table 256 x 24 (8 per gun)

MONITORS		
	14"	$1,630
	19"	$4,750
NTSC ENCODER	N/A Yet	
HARD COPY FACILITY	Working on Applicon and Hard Disk interfaces	
COST OF BASIC SYSTEM	512 x 512 x 8	$19,820
DESIRED EXTRAS	included	-
TOTAL COST		$19,820
COMMENTS	Tektronix emulation mode - Unmodified Plot-10 (4000) included No character generator Working on floppy disk interface to unibus $4,000	

SYSTEM: Three Rivers CC	CONTACTS: (412) 621-6250	Recommend purchase at McAir (FRA 1978)
IMAGE MEMORY CONFIGURATIONS AND COSTS	Memory acts as add-on to PDP-11 Memory. It is much smaller than other image memories since display information is compacted to RLE format.	
PROCESSOR	Controls Run-Length encoding and decoding.	
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION	
REFRESH RATE	30 Hz	
INTERLACE		
HOST	PDP 11/70 Extended PDP-11 memory - difficult on 11/70	
INTERFACES	VAX	
PERIPHERALS	Tablet	$1,500

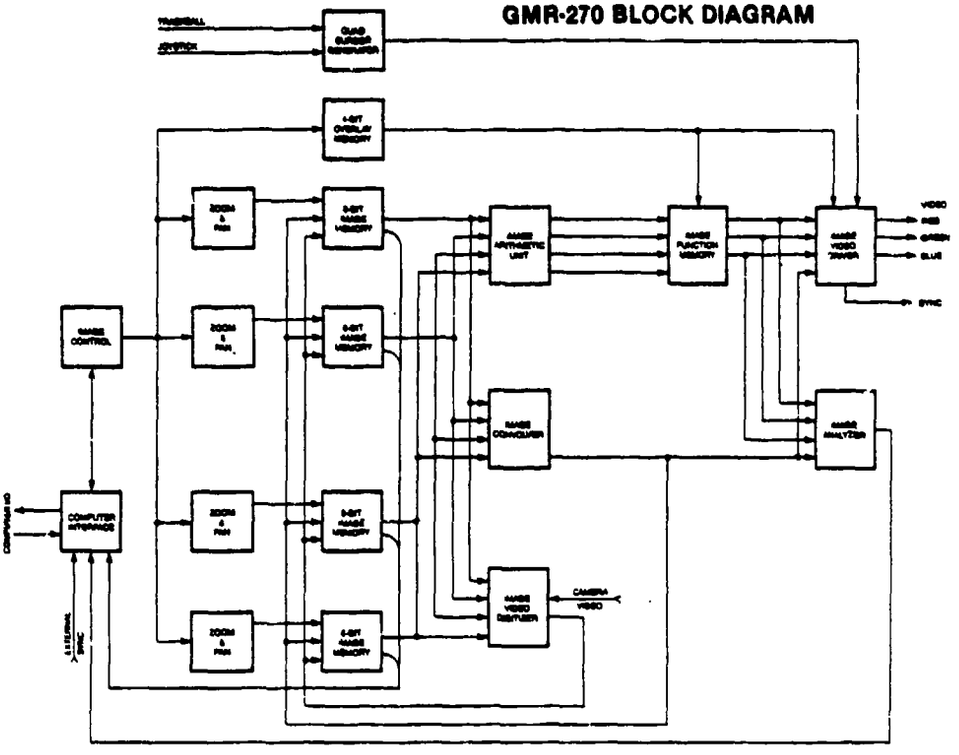
FACILITIES (H-HARDWARE, F-FIRMWARE, S-SOFTWARE, U-USER/PROCESSOR)		
	H	Run-Length Encode/Decode
	H	Color Map 64 x 16 (5 per RGB, 1 for repeat line)
MONITORS		
NTSC ENCODER		
HARD COPY FACILITY		
COST OF BASIC SYSTEM		≈ $20,000
DESIRED EXTRAS		
TOTAL COST		
COMMENTS	Note: This system is designed for animation of simple imagery .... primarily of accounting information. It would not be suitable for display of continuous surfaces.	

SYSTEM Grinell GMR-27	**CONTACTS** John Metzler (408) 263-9920 San José, CA		
IMAGE MEMORY **CONFIGURATIONS AND COSTS**	512 x 512 x 1 bit planes quantities: 1 - $800 2 - $1200 3 - $1600 4 - $2000 (max 32 planes)		
PROCESSOR	Not user programmable		
MEMORY ACCESS	**ONE PIXEL I/O AFTER INITIALIZATION** 6 Msec first pixel ~1.5 Msec subsequent pixels		
REFRESH RATE	30 Hz	60 Hz	
INTERLACE	2:1	1:1	
HOST	**PDP 11/70** Get DR11B from Dec. - Interface logic		$500
INTERFACES	**VAX** Similar		
PERIPHERALS	Joystick Trackball		$700 $2,500

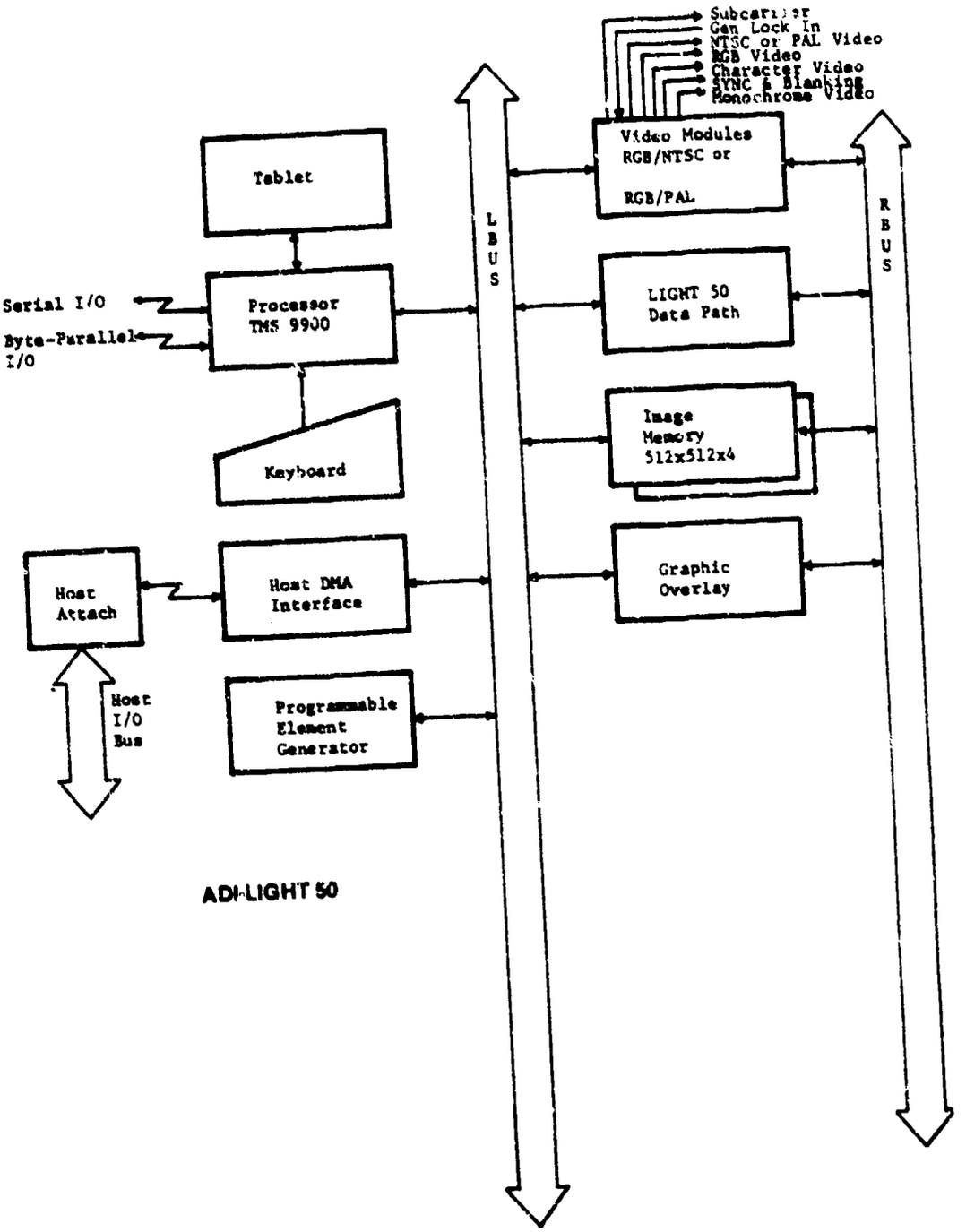
FACILITIES **H-HARDWARE** **F-FIRMWARE** **S-SOFTWARE** **U-USER/PROCESSOR**			
	H	Vectors, Rectangles, Characters 1.5 Ms/pixel	included
	H	Scroll	included
	H	dot Cursor that blinks	included
	H	Image Function Memory Card $1600 (requires Video Drive Card) - (3) 1024 x 8 color tables - capability for split screen and image toggling	$1,200
	H	4 extra cursors	$1,000

MONITORS	buy and resell Conracs
NTSC ENCODER	
HARD COPY FACILITY	
COST OF BASIC SYSTEM	controler $5000, Memory $4000, Interface logic $500 & DRIIB, Monitor $15,000
DESIRED EXTRAS	Image Function Memory Card, Video Drive Card,
TOTAL COST	Joystick, Trackball $22,000
COMMENTS	Video digitizing option $1200

GMR-270 BLOCK DIAGRAM



SYSTEM Grinell GMR-270	**CONTACTS** John Metzler (408) 263-9920 San José		
IMAGE MEMORY	512 x 512 x 1 bit planes		
CONFIGURATIONS AND COSTS	quantities: 1 - $800 2 - $1200 3 - $1600 4 - $2000 (Max 32 planes)		
PROCESSOR (SEE ATTACHED)	Not User Programmable		
MEMORY ACCESS	**ONE PIXEL I/O AFTER INITIALIZATION**	6 Msec first pixel 1.5 Msec subsequent pixels	
REFRESH RATE	30 Hz	60 Hz	
INTERLACE	2:1	1:1	
HOST	**PDP 11/70** Get DR11B from Dec - Interface Logic		$500
INTERFACES	**VAX** Similar -		
PERIPHERALS	Joystick		$700
	Trackball		$2,500
FACILITIES			
H-HARDWARE	H	Zoom (2x, 4x, 8x) and Pan With cursor to denote screen center	$1,200
F-[illegible]WARE	H	(3) 256 x 24 color tables (use only one at a time)	$1,600
S[illegible]TWARE	H	Image Function Memory Card $1600 (Video Driver Card $1200) - 3 1024 x 8 color tables - capability for split screen and image toggling	
USER/PROCESSOR	H	Image Processor Card (multiply, divide...)	$2,200
	H	Image Analyzer Card (histograms...)	$1,400
		Window read and write control	included
MONITORS	buy and sell Conracs		
NTSC ENCODER			
HARD COPY FACILITY			
COST OF BASIC SYSTEM			$15,000
DESIRED EXTRAS	com/Pan, Image Function Memory Card, Video Drive Card, Joystick, Trackball		$23,200
TOTAL COST			
COMMENTS	Video Digitizing Option $1200		

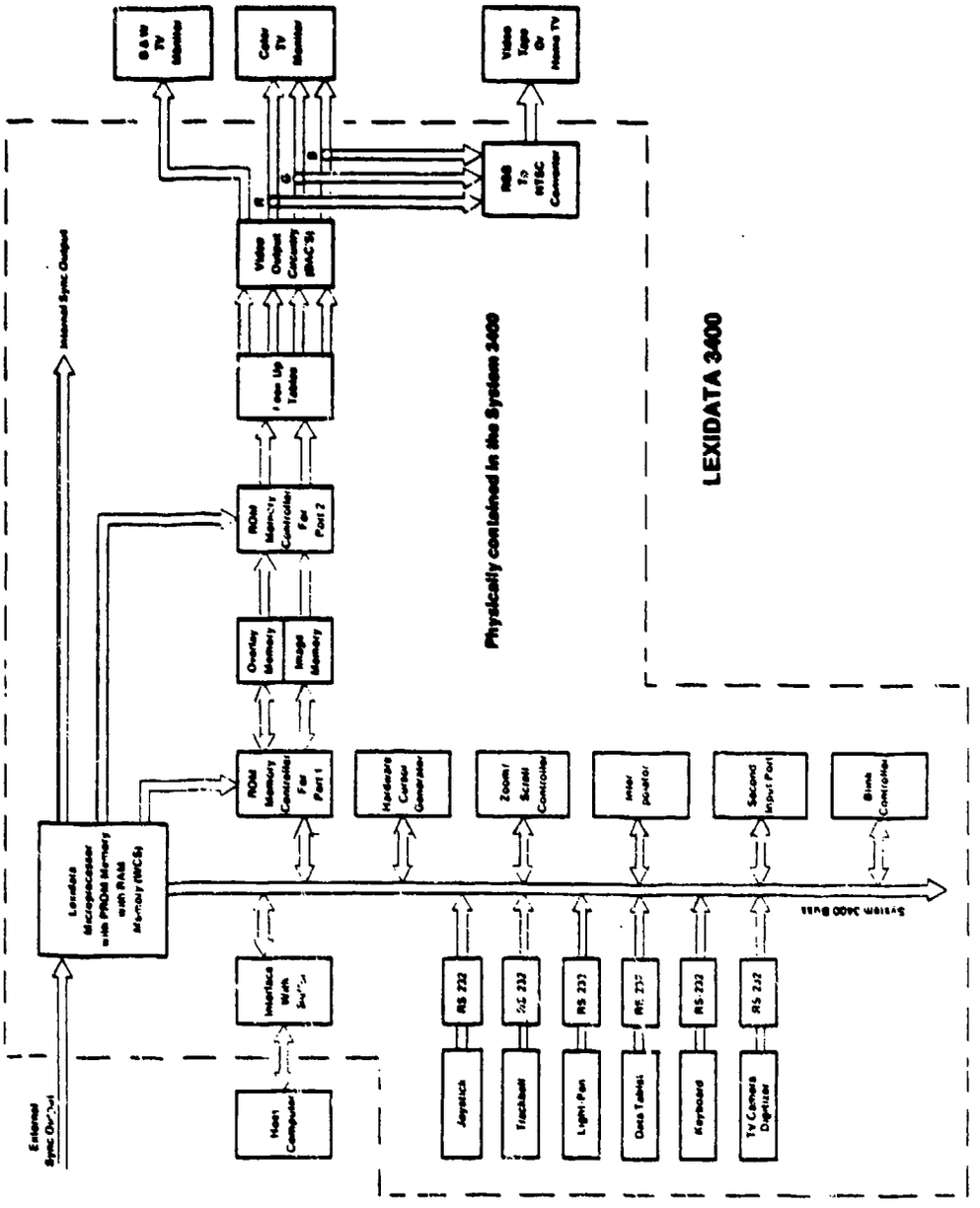

Subcarrier
Gen Lock In
NTSC or PAL Video
RGB Video
Character Video
SYNC & Blanking
Monochrome Video
Tablet
Video Modules
RGB/NTSC or
RGB/PAL
L
B
U
S
R
B
U
S
Serial I/O
Byte-Parallel
I/O
Processor
TMS 9900
LIGHT 50
Data Path
Image
Memory
512x512x4
Keyboard
Host
Attach
Host DMA
Interface
Graphic
Overlay
Host
I/O
Bus
Programmable
Element
Generator

ADI-LIGHT 50

SYSTEM ADI - Light 50	CONTACTS	Harold F. Clearwaters (Main) Bob Ray - local salesman Lowell, MA (617) 459-2578	
IMAGE MEMORY CONFIGURATIONS AND COSTS	512 x 512 x 4 board - Max 4 now, 8 future (1024 x 1024 display not announced yet)		$2,500
PROCESSOR (SEE ATTACHED)	16 bit Micro - TMS 9900 - User can download 8k ROM & 4k RAM which can be increased		
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION	1.2 Ms	
REFRESH RATE	30 Hz		
INTERLACE	Yes		
HOST	PDP 11/70 interface w/micro → host attachment → host I/O bus		$2,500
INTERFACES	VAX N/A		
PERIPHERALS	Keyboard with numeric pad & 16 function switches Joystick		$600 $200

FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR		
	H	1 pix (vertical) by 16 pix (horizontal) scroll and zoom 2x, 4x, 8x $500
	H	Fast Element Generator (fill 2.5 Ms/pixel)(Vectors 1.3 Mx/pixel) $3,000
	H	Graphics Overlay - RS170 (camera input)(512 x 512 x 1 plane) $2,500
	H	Color table 256 x 16 (standard) 1024 x 16 (optional -) (5-red 6-blue 5-green)
	F	Included - arbitrary (real) scaling 1x to 256x - must rebuild image - generate circles, arcs, characters, rectangles, conics - area fill and rectangle fill - cross-hair cursor - multiple views with a 2D window (function of zoom & scroll)

MONITORS	N/A	
NTSC ENCODER	Yes	Included
HARD COPY FACILITY	Tektronix hard copy- hook-up RS170 & Child System	
COST OF BASIC SYSTEM		$19,000
DESIRED EXTRAS	Zoom/scroll, Prog. element generator, keyboard, joystick	$23,300
TOTAL COST		
COMMENTS	Teklight - Tek emulator Prom Can overlay text Child System S & S electronics dropped Genisco & Ramtek - ADI looks good.	$850

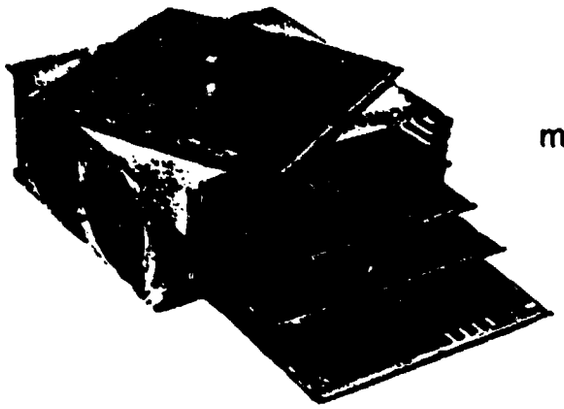

LEXIDATA 3400
Physically contained in the System 3400
B & W TV Monitor
Color TV Monitor
Video Tape Or Home TV
RGB To NTSC Converter
Video Output Circuitry (RAC'S)
Internal Sync Output
Look Up Tables
ROM Memory Controller For Port 2
Overlay Memory
Image Memory
ROM Memory Controller For Port 1
Hardware Cursor Generator
Zoom/ Scroll Controller
Inter pointer
Second Input Port
Blink Controller
System 3400 Bus
Interface With System
RS 232
Joystick
Trackball
Light Pen
Data Tablet
Keyboard
TV Camera Digitizer
Host Computer
External Sync Output

SYSTEM: Lexidata 3400	CONTACTS: Art Frankie Burlington, Mass. (617)273-2700	
IMAGE MEMORY		
CONFIGURATIONS AND COSTS	512 x 512 x 1 plane (Max 16) 1024 x 1024 x 1 plane (Max 4)	$1120 $4480
PROCESSOR (SEE ATTACHED)	12 bit Micro with 1k-3k PROM & 1k RAM for Writable Control Store difficult user programming (2k-12k)	
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION ~1 Ms	
REFRESH RATE	(512) 30 Hz (512) 60 Hz (1024) 30 Hz	
INTERLACE	2:1 1:1 2:1	
HOST	PDP 11/70 recommend 16 bit parallel DMA interface to Unibus	$1200
INTERFACES	VAX similar	
PERIPHERALS	w/RS232 joystick keyboard trackball tablet (dropped lightpen support)	$1400 $ 900 $2500 $2000

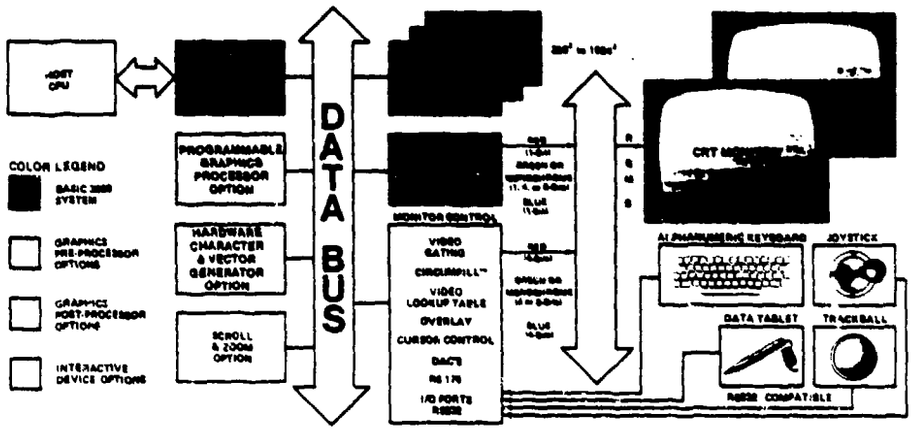
FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR			
	H	Zoom (1x, 2x, 3x, 16x) and Scroll	$1000
	H	for 8 bit depth 256 x 24 (8 per RGB) Maximum of 1024 x 24 simultaneous	$3405
		Blink controller	
		Multiple overlays	
		RAM add-on for micro	$ 500
	F	Image Display Operating System - accessible via Software Driver which is resident on host. -vector generation each vector : 10Ms + 2Ms per pixel -ramp feature for color look-up -movie feature using zoom and scroll	
		Cursor	$ 700

MONITORS	512^2 resolution	$ 3,000
	1024^2 resolution	$8,000 to $13,000
NTSC ENCODER	optional	$ 3,000
HARD COPY FACILITY	Tektronix hardcopy	$ 7,500
COST OF BASIC SYSTEM		~$20,000
DESIRED EXTRAS	Joystick, keyboard, tablet, zoom/scroll, RAM add-on	~$25,800
TOTAL COST		
COMMENTS		

GENISCO DIGITAL DISPLAY SYSTEMS



Setting a new criteria of modularity, display dynamics, performance, reliability, processing speed and cost-effectiveness!



Completely programmable, Genisco Digital Graphic Display Systems are modularly expandable to cover the widest range of application requirements. You specify the features and options you need. Genisco graphic display experts, using functionally proven "building-block" modules, tailor systems that cost-effectively answer that need . . . dynamically, efficiently and reliably!

Basic 3000 System. Consists of the proper CPU interface, fast entry MOS/RAM Refresh Memory Modules – with read/write, word or bit capabilities, automatic DMA access for block transfers to 833K 16-bit words/second – and the Video Control, that generates the basic system timing and formats the output for RS170 waveforms.

Pre-Processor Options. The GCT-3011 Programmable Graphic Processor, under control of its own program that is easily modified, converts data that includes both vectors and characters, and routes it to the memory modules. A Hardware Character/Vector Generator is also available for very fast dynamic applications.

Post-Processor Options. Monitor Control Modules, in a number of optional configurations, provide added capability to the system such as Video Gating, Circumfill™, Video Lookup and Readback Overlay, Cursor Control, DAC's, RS232 I/O Ports, and RS170 composite video waveforms. A Scroll and Zoom – by image or plane – is also optionally available.

Interactive Device Options. RS232 compatible interactive devices like an ASCII Alphanumeric Keyboard with 16 lighted function switches, Trackball and Joystick, and an 11" x 11" Graphic Data Tablet are available from Genisco.

For particulars on your specific digital graphic display requirements, contact Genisco – a name that has stood for advanced technology over the past 30 years.

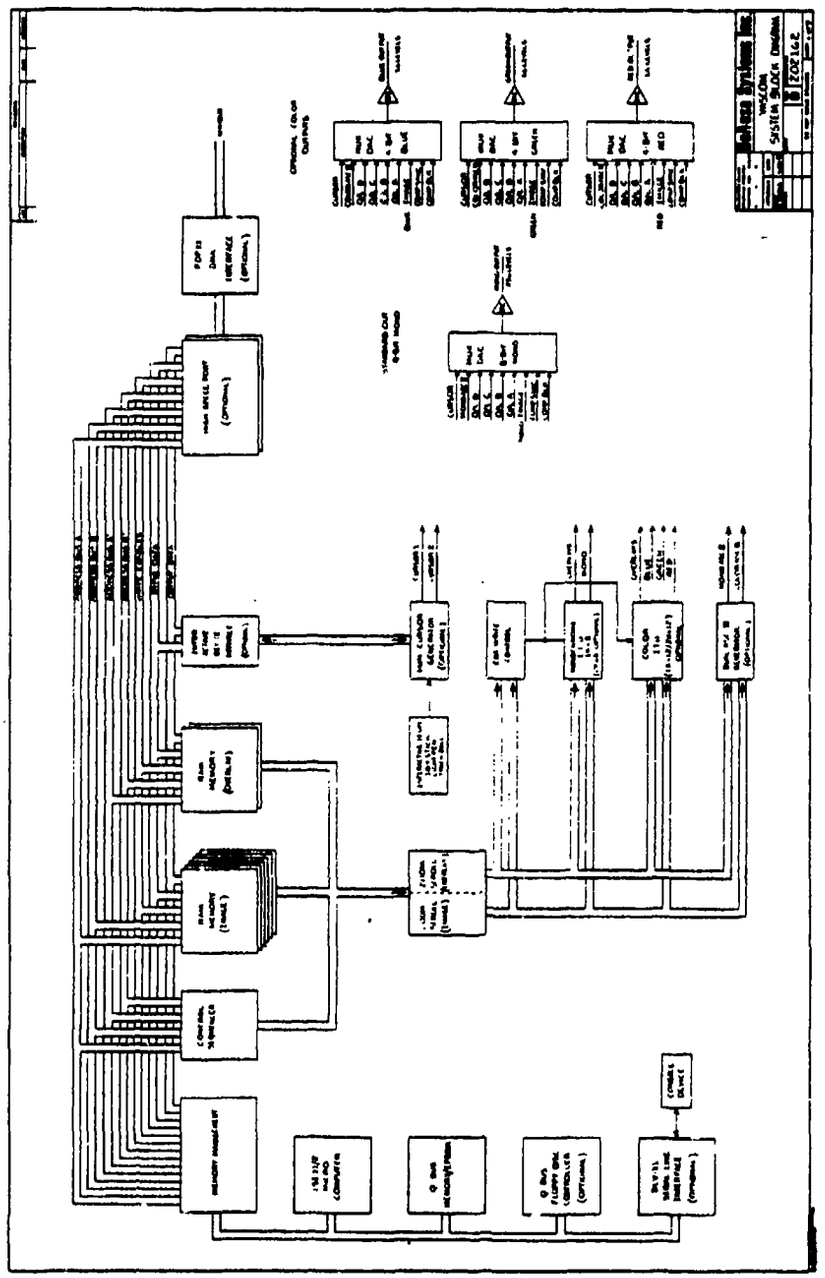
SYSTEM Genisco GCT-3000	CONTACTS	Stu Robert (UP) Bob Ray (salesman) Lowell, Mass (617)459-2578	Joe Tublan Dan Jones	Bob Frey (UP) Dave Pauley Irvine, CA	
IMAGE MEMORY					
CONFIGURATIONS AND COSTS	512 x 512 x 1 plane 1024 x 1024 x 1 plane Max of 14 planes in 2 chassis				$1500 $2500
PROCESSOR (SEE ATTACHED)	Programmable Graphics Processor (PGP) Graphic Operating System takes about 1/2 of the 4k RAM				
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION				
REFRESH RATE	(512) 60 Preferred	40, 30 Hz	(1024) 30 Hz		
INTERLACE	1:1	Yes 2:1	Yes 2:1		
HOST	PDP 11/70 (RSX11-M available) Note: Driver w/demos = $560				$1700
INTERFACES	VAX				$1700
PERIPHERALS	keyboard trackball joystick tablet				$1350 $2900 $1000 $1500

FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR			
	H	Character/vector generator ~10 Ms per pixel	$2000
	H	Scroll and Zoom (2x, 4x, 8x)	$1300
	H	Color Table 256 x 24	included
	H	Fill Mode - will fill between vectors (max 4 planes)	included
	H	Cursor and blink control in lieu of second cursor	included
	S	Graf pac II - fortran callable graphics subroutine library includes: area fill, some 2D translations, curves, lines, vectors, text control	$3000

MONITORS	512 x 512 1024 x 1024	$ 3,240 $15,200
NTSC ENCODER		$ 4,500
HARD COPY FACILITY		
COST OF BASIC SYSTEM		$20,700
DESIRED EXTRAS	keyboard, joystick, tablet, character/vector generator, zoom/scroll, Graf pac II	
TOTAL COST		$31,050

COMMENTS

-vectors must be erased for movement, hardware fissoring
-character controls: 1x...16x zoom, 90° rotation, programmable fonts
-plot-10 emulator available
-rumors of hardware problems from users

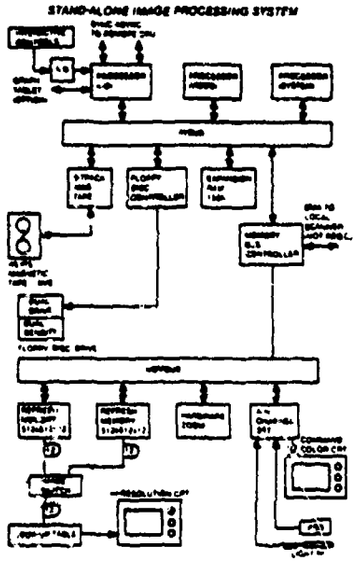


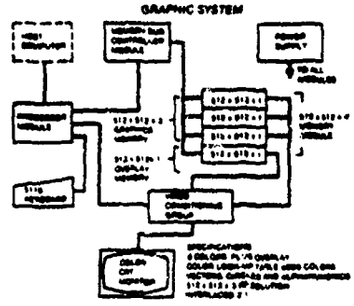
SYSTEM DeAnza VC5000	**CONTACTS** Rick Pizza Chuck Nordby San José, CA (408) 263-7155	
IMAGE MEMORY **CONFIGURATIONS AND COSTS**	All systems are 512 x 512 x 16 System #1. Monochrome - 8 bits intensity, 4 overlay, 4 aux. System #2. Color 12 bits RGB (4 per gun), 4 overlay	
PROCESSOR	LSI-11 totally user programmable (24K bytes)	
MEMORY ACCESS	**ONE PIXEL I/O AFTER INITIALIZATION** 1.2 Ms	
REFRESH RATE	30 Hz	
INTERLACE	2:1	
HOST	PDP 11/70 RSX11-M requires special high speed interface: Port $1,950 (Card) Dmb $1,475	
INTERFACES	VAX	
PERIPHERALS	Joystick (cursor) ADM-3 Dumb Terminal	$875 $1,250

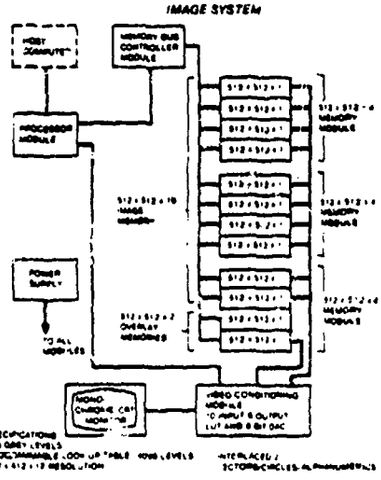
FACILITIES **H-HARDWARE** **F-FIRMWARE** **S-SOFTWARE** **U-USER/PROCESSOR**			
	H	Color Tables with Image Transform Control - "Psudo Color" Monochrome 2048 x 8 Color 1024 x 12 (4 per color) Color 2048 x 12 (4 per color)	 $400 $1,950 + $2,000
	H	Dual Cursor (different modes)	$1,400
	H	Zoom (2x, 4x, 8x) and Scroll	included
	S	Vector Generation 8.5 Ms/pixel	included
	F	Character Control ($1,000) w/Color	$1,500

MONITORS		
NTSC ENCODER		
HARD COPY FACILITY	Recommend Dunn	
COST OF BASIC SYSTEM	including 1024 x 12 color table	~$11,400
DESIRED EXTRAS	joystick, terminal, cursor	$34,950
TOTAL COST		
COMMENTS	-Designed to stand alone - terminal and floppy -Image from floppy approx. 11 sec.	$4,450

Typical Model 5216 System Configurations

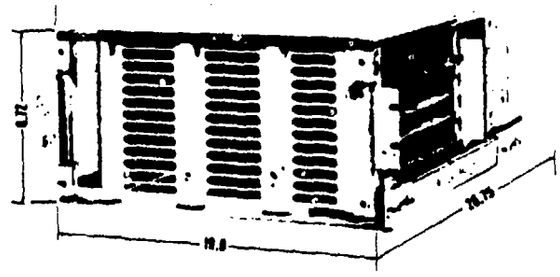






Mechanical Configuration

The Model 5216 is packaged in a fan cooled 19 inch rack-slide mountable chassis. Eleven module or full card slots are provided per chassis — some modules require only half cards. Up to three chassis may be linked together to form a 33 module configuration. Each chassis is self powered by means of a rear mounted, self-contained, power module. All connections are made via backplane mounted connectors. Side entry of plug-in modules allows full access to card-edge connections as well as the printed back planes when the chassis is extended on the slides.

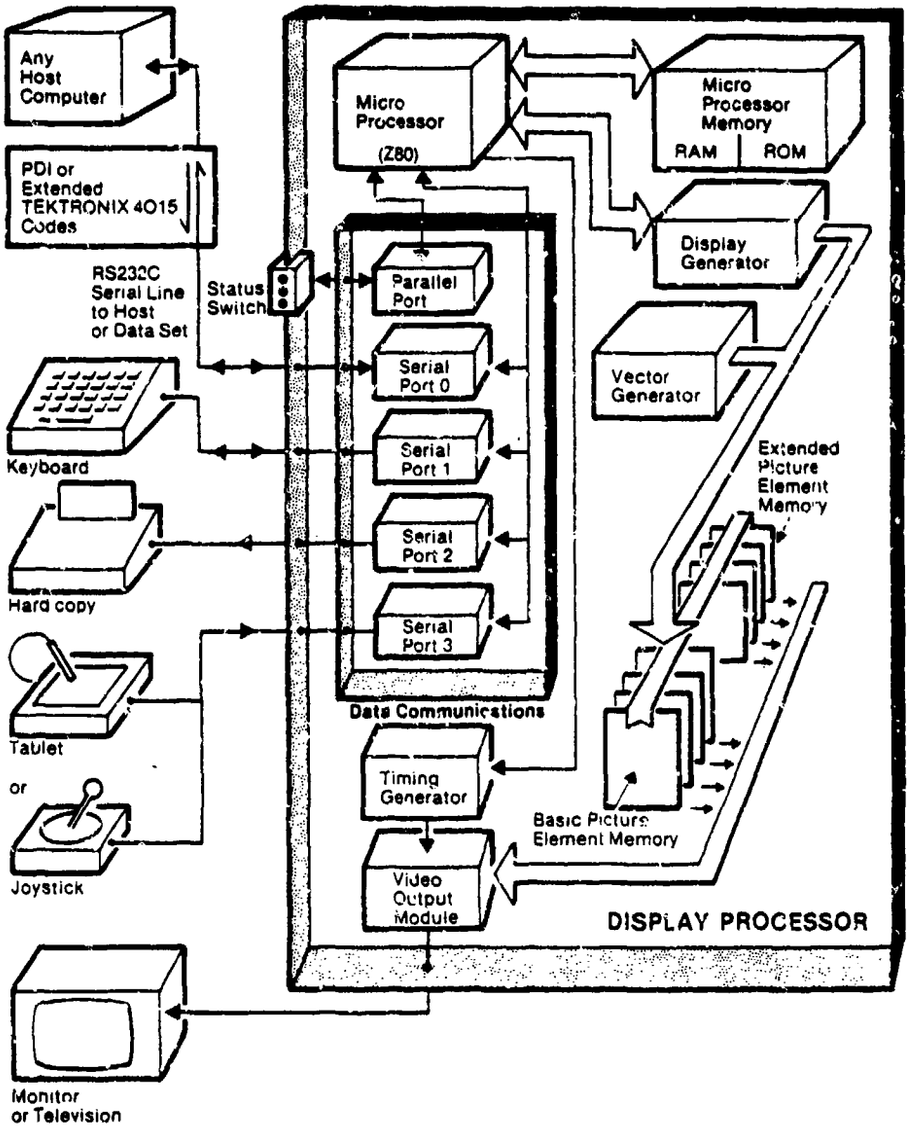


SYSTEM	CONTACTS		
Aydin 5216	Ralf Hubert (Sales) (617) 649-6754 Mass. (617) 649-7472 (home)	Customer: Ron Melanson DEC (617) 481-9511 Ext. 6419	
IMAGE MEMORY CONFIGURATIONS AND COSTS	512 x 512 x 1 bit plane (no sense) 1024 x 1024 x 1 bit plane Maximum of 16 planes		$2000 to $2200 $2500 to $2750
PROCESSOR (SEE ATTACHED)	Intel 8086 - up to 1 Mega word user programmable using Forth language		
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION ≤ 1 Hs		
REFRESH RATE	(256x256) 60 Hz	(256x256) 30 Hz	(512x512) 60 Hz (512x512) 30 Hz (1024x1024) 30 Hz
INTERLACE	1:1	2:1	1:1 2:1 2:1
HOST	PDP 11/70 DMA - DR11B interface		$ 850
INTERFACES	VAX Same		$ 850
PERIPHERALS	keyboard with 10 function keys lightpen 45 function keys $835 joystick trackball	90 function keys	$ 900 $ 995 $1470 $ 690 $2895

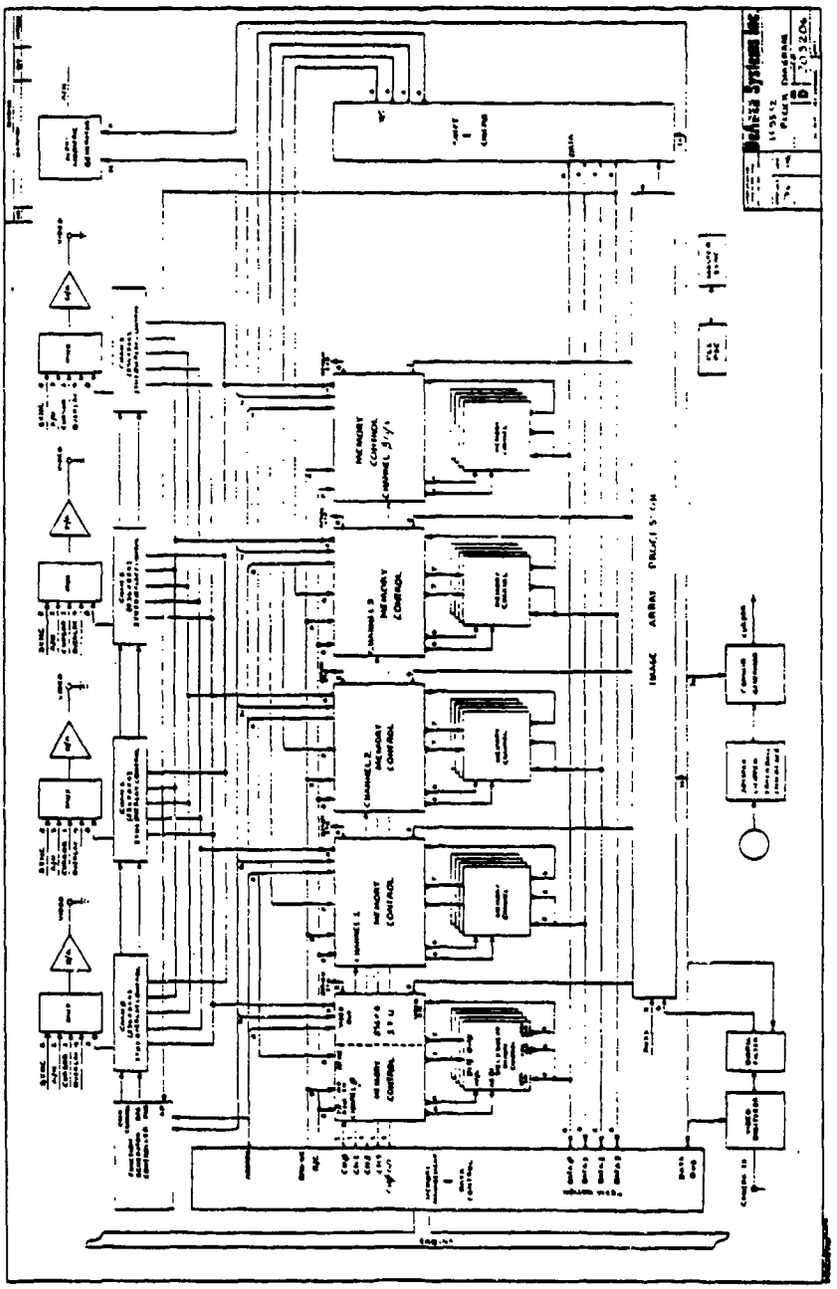
FACILITIES				
H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR	F & H	H	Vector & Circle Generator (10x firmware speed?)	$3500
		H	Zoom Control (2x, 4x, 8x, 16x) and Scroll	FQ
		H	Alphanumeric Channel Module	
		H	Cursor included with device controller	
		H	Color Table 2048 x 12 (or 4096 x 6) 4 per RGB +Additional modules to provide 8 per RGB	$3000
	F & S	S	AYGRAF (4 different versions) SIGGRAPH/CORE Version -polygon fill with firmware -Z-depth sort of polygon filled areas (hidden surface) -curve fitting & generation, conics, polar coordinates -color control with percent of hue, intensity & saturation -2D & 3D manipulation and windowing	$7500

MONITORS	(8024) - 13" diagonal - 800 TV lines	$3075
	(8025) - 19" diagonal - 900 TV lines	$2395
	(8026) - 19" diagonal - 1000 TV lines	$7435
NTSC ENCODER		
HARD COPY FACILITY		
COST OF BASIC SYSTEM	with 8 bit per RGB color table	$30,000
DESIRED EXTRAS	keyboard, lightpen, joystick, vector generator zoom controller w/scroll, AYGRAF CORE	$42,500
TOTAL COST		
COMMENTS	upgrade to ultra-high (1024x1024) resolution requires: -change some PROM chips, firmware & possibly backplane -monitor (changes are supposed to be minor)	

Block Diagram

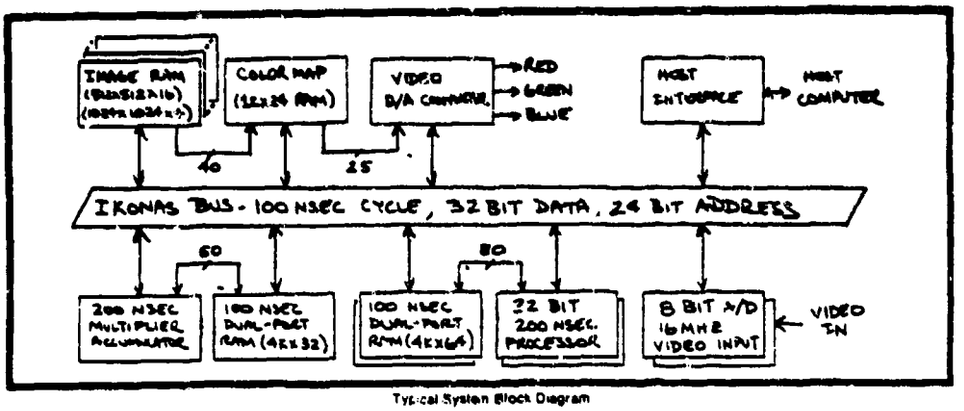


SYSTEM Norpak VDP	**CONTACTS** Bill Lalond Pakenham (Ottawa) 1-613-624-5507, 5570	
IMAGE MEMORY **CONFIGURATIONS AND COSTS**	Two basic configurations newer: 512 x 512 x 4 for 512 or 1024 displays older: 1024 x 512 x 1 for 512 displays only	 $3500 ≈$1750
PROCESSOR (SEE ATTACHED)	Bit slice micro-Fortran calls to access micro-instructions Not user programmable - can down load somewhat	
MEMORY ACCESS	**ONE PIXEL I/O AFTER INITIALIZATION** 1.5 Ms	
REFRESH RATE	(512) 25, 30 Hz 50, 60 Hz (1024) 25, 30 Hz	
INTERLACE	2:1 1:1 2:1	
HOST	**PDP 11/70** Modified DR11B - DMA - Limited to DEC(s)	$2800
INTERFACES	**VAX**	
PERIPHERALS	keyboard with numeric/cursor pad, 32 function switches, 8 lights trackball joystick tablet touch sensitive display	$1300 $3300 $1900 $2000 (future)
FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR	F Firmware included -Points, vectors, arcs, polygons, text ~1.5 Ms^{+} per pixel -Scroll (w/hardware) - each bit plane separately -Zoom 2x, 4x, 8x (w/hardware) -can use to do subwindows on screen (vwport) -Polygon fill and area fill -Run-length encode and decode -Cursor in overlay H Color table 256 x 24 display and 256 x 4 overlay incl. S Fortran callable routines to access micro-instructions S SIGGRAPH CORE - not complete, waiting on SIGGRAPH	 $ 350
MONITORS	Recommend Conrac	
NTSC ENCODER		
HARD COPY FACILITY	Micro-controlled interactive input & Rs232 output firmware drive	$3500
COST OF BASIC SYSTEM		~$35,000
DESIRED EXTRAS	keyboard, joystick, tablet, Fortran interface, input/output drive (need for peripherals)	~$44,000
TOTAL COST		
COMMENTS	System is not really completed as yet, hard to pin down.	



IP 5000 SYSTEM

SYSTEM DeAnza IP5000	CONTACTS Rick Pizza Chuck Nordby San José, CA (408) 263-7155	
IMAGE MEMORY CONFIGURATIONS AND COSTS	All systems are essentially 512 x 512 x 24 bits System #1 2 channels (1 scratch) monochrome 8 bits System #2 3 channels RGB 8 bits per color gun System #3 4 channels (1 scratch) RGB w/3 overlay planes	
PROCESSOR (SEE ATTACHED)	Pipe-line Array Processor - user programmable	
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION 800 Ns	
REFRESH RATE	30 Hz	
INTERLACE	2:1	
HOST	PDP 11/70 Treated as virtual memory-off UNIBUS by use of registers.	
INTERFACES	VAX	
PERIPHERALS	joystick w/interface trackball w/interface lightpen w/interface	$ 875 $3450 $2950
FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR	H Vector generator - 2.5 Ms (estimate) per pixel H Zoom and Scroll (zoom 2x, 4x, 8x) H Color Maps 3 256 x 24 maps - display only one -ITU - Image Translator - secondary color control H Cursor F Image processing functions ... for example: -can add two 512 x 512 x 8 images in 1/30 sec. -multiply two 512 x 512 x 8 images in 3/10 sec. -can split screen with separate look-up tables Alphanumeric overlay generator	$1400 ($4600) $1000
MONITORS		
NTSC ENCODER	N/A	
HARD COPY FACILITY	Recommend Dunn	
COST OF BASIC SYSTEM		$42,000
DESIRED EXTRAS	joy-tick, lightpen, ITU, alpha/num generator overlay	$48,025
TOTAL COST		
COMMENTS		



Typical System Block Diagram

PROCESSOR

The IKONAS processor is fully user programmable. A fast, 32 bit wide architecture gives unparalleled precision for graphics and image processing applications. The IKONAS processor speeds image computation by executing many repetitive, time consuming calculations from microcode programs. Graphics and image processing performance is further enhanced by allowing the host computer direct access to the image memory as well as to any other memory on the IKONAS bus (color look-up table, microcode store, etc.).

IMAGE MEMORY

IKONAS Image Memory is bit plane organized. Each module can be addressed as 1024x512x1, 512x512x2, or, for multi-pixel access, as 16Kx32. Pan, and scroll in pixel increments are standard as is zoom to any integer ratio 1:1 to 256:1. Modular nature of the units allow memory to be easily expanded from 512x512x2 up to 512x512x32 or 1024x1024x16.

FAST HARDWARE MULTIPLIER

The multiplier accumulator module facilitates the rapid execution of many graphics and image processing tasks which require multiply then add or subtract cycles, e.g. matrix multiplication (3-D point transformation), vector dot and cross product (shade calculations), and weighted averaging (anti-aliasing). Four modules operating in parallel allow sub-microsecond 3-D point transformation.

VIDEO INPUT

Video signals may be written into the image memory in real time. The high speed bus architecture of the IKONAS system allows simultaneous 10 Mbyte/sec video input, 10 Mbyte/sec video output, and 2 Mbyte/sec host data transfer.

ANIMATION

Computer graphics animation is a fast developing field with applications in: physical system modeling, display of time varying data, and cartooning. IKONAS systems support computer animation using color-map or run-length encoding techniques with a variety of color look-up tables and run-length decoders. Image Memory serves as a run-length animation buffer for encoded images as well as frame buffer for unencoded images. The Mass Image Storage module can hold up to 60 seconds of moderately complex animation for real-time playback or can be used to store unencoded images.

FLEXIBILITY, EXPANDABILITY

IKONAS systems are entirely modular, being configured from various modules attached to a common communication bus. Systems are easily expanded. One cage holds 20 cards, multiple cage configurations are possible. A user can begin with a simple frame buffer and add processor, image input, and hardware multiplier modules later.

CUSTOMIZED SYSTEMS

Modular design of components means that systems are configured to meet a customer's particular needs. Extensive use of microprogrammed controllers in the modules means that custom modifications are easily performed in many cases. A wide variety of options is available. IKONAS is particularly interested in providing state-of-the-art hardware for research and special purpose graphics and image processing systems.

SYSTEM IKONAS	CONTACTS Mary Whitten or Nick England Raleigh, NC (919) 813-5401	
IMAGE MEMORY		
CONFIGURATIONS AND COSTS	1024 x 512 x 1 Max of 20 cards	$2000
PROCESSOR (SEE ATTACHED)	Big and fast 32 bit 200 Ns Microprocessor (almost 50% cost of the total system)	
MEMORY ACCESS	ONE PIXEL NO AFTER INITIALIZATION 400 Nsec access 100 Nsec on bus (1 cycle) ... 4 cards can operate in alt. 100 Ns	
REFRESH RATE	(512) 30 Hz (512) 60 Hz (512) 50 Hz (512) 100 Hz (1024) 30 Hz	
INTERLACE	1:2 1:1 1:1 1:2	
HOST	PDP 11/70 DMA via DR11B	$3000
INTERFACES	VAX Same	
PERIPHERALS	none as yet - peripherals are hung off the host	

FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR		
F	(Pan) Scroll & Zoom (1x, 2x, 3x, 4x, 5x, ... 256x)	included
H	Run-[illegible] Encode/Decode ... animation possible	$2400
F	Win[illegible]ow and Viewporting	
H	Cursor	
H	Color Table 1024 x 24 Low Speed: $2000 High Speed: $2800 (Required for 1024 x 1024)	
U	Possible things to look for: -fast vector generation (NASA) -"real time" hidden-line/surface (NASA) -2D & 3D model manipulation -Edge detection and anti-aliasing	

MONITORS	
NTSC ENCODER	Recommend Lenco
HARD COPY FACILITY	Recommend Dunn
COST OF BASIC SYSTEM	~$45,000
DESIRED EXTRAS	RLE Encoder/Decoder
TOTAL COST	~$48,000
COMMENTS	"Look for good things from Ikonas ..." (AED engineer) -advertised as tool for graphics research -no high-level language interaction -upgrade to ultra-high resolution requires one software bit change!

The following paragraphs briefly describe the various elements of the RM-9400 Display Generator

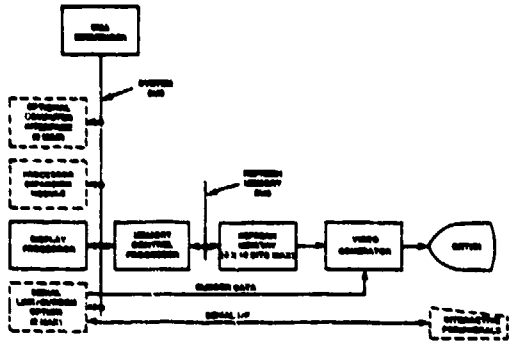


FIGURE 1. RM-9400 FUNCTIONAL BLOCK DIAGRAM

• Computer Interface (RM-9000-XX)
The Computer Interface provides a high-speed link between the host computer and the RM-9400 Display Generator. A general purpose interface (GPIF) is provided on the Display Processor. Two additional card slots are reserved for custom interfaces. Off-the-shelf interfaces are available for most minicomputers and some large mainframes. All interfaces are 16-bit parallel. Most incorporate or utilize direct memory access.

• DMA Sequencer
The TTL DMA Sequencer performs high-speed, non-processor transfers involving multiple devices on the System Bus, for example, between the Computer Interface and Display Processor or Memory Control Processor. The DMA Sequencer can involve as many as 14 ports and seven subloops.

• Display Processor
The Display Processor directly or indirectly controls each element of the display system. In addition, it decodes received instructions, stores subpictures (command lists), and fonts, performs coordinate transformations, and drives the Memory Control Processor. The Display Processor contains a Z80 microprocessor with 32K bytes each of EPROM and RAM, a GPIF interface, three serial ports, a timer, memory map, cycle-stealing DMA and interrupt control logic. The memory map accommodates up to 512K memory bytes, of which 96K bytes are reserved for internal control software.

• Processor Expansion Module (RM-9400-PEM1, 2, 3, 4)
The Processor Expansion Module adds a high-speed math unit, up to 32K bytes EPROM potential, and additional user RAM to the Display Processor. Memory expansion may be specified in 32K byte increments to a maximum of 128K bytes (where n = number of 32K byte increments).

• Memory Control Processor
The Memory Control Processor draws primitives, alpha-numerics, graphics, images, etc., into the refresh memory and performs clipping, entity detection, pan and zoom. The MCP contains a special-purpose 16-bit bipolar microprocessor with dedicated ROM, RAM and support logic.

• Refresh Memory (RM-Y/X, Z)
The Refresh Memory consists of solid-state MOS RAMs that store the picture(s) in raster scan, dot matrix format. The memory is organized as one to eight groups of up to 16-bits each. Each 16-bit cell defines a single pixel on one or more CRTs. Table 1 lists the possible resolutions, aspect ratios, and refresh frequencies.

TABLE 1—RM-9400 RESOLUTION TABLE

Controller Model (RM-9400/MX)	Spatial Resolution		Aspect Ratio (X:Y)		Refresh Frequency (Frame Rate)
	Lines	Elements	Raster	Pixel	
RM-9400-1X	256	640	4:3	2:1	50, 60Hz Repeat Field
RM-9400-4X	512	512	1:1(1)	1:1	50, 60Hz Repeat Field
RM-9400-5X	512	640	4:3	1:1	50, 60Hz Repeat Field
RM-9400-6X	512	1024	1:1(1)	2:1	50, 60Hz Repeat Field
RM-9400-7X	512	1280	4:3	2:1	50, 60Hz Repeat Field
RM-9400-8X	1024	1024	1:1(1)	1:1	25, 30Hz Interlaced
RM-9400-9X	1024	1280	4:3	1:1	25, 30Hz Interlaced

Note: (1) Active raster is centered within 4:3 CRT aspect ratio.

• Serial Link/Cursor Option (RM-9400-SLC2/4)
The Serial Link/Cursor option processes operator input from keyboards and graphic input devices, and generates two or four independent cursors that can be used to point to the face of the display without affecting the data in refresh memory. The RM-9400-SLC consists of a Z80 microprocessor with dedicated ROM and RAM, four or eight serial ports and two or four 32 x 32 programmable cursor generators. Support software is available for keyboards, joysticks, trackballs, light pens and graphic tablets.

• Video Generator (RM-9400-Vn)
The Video Generator transforms the stored pictures into industry compatible video signals that drive Ramtek or other commercially available high resolution CRT monitors, large screen projectors and hardcopy printers. All outputs are compatible with EIA Std. RS-170 or RS-343-A specifications for composite video.

The video generators process data on a pixel-by-pixel basis through PROM or RAM defined lookup tables that assign output color and/or intensity. Each pixel indexes the lookup table as it is scanned from the refresh memory. The contents of the addressed cell in the lookup table are then passed to the digital-to-analog converters (DACs) or video amplifiers that produce the output video signals.

Cursor and overlay mixing is performed either in the lookup table or at the DAC by clamping the output voltage to minimum or maximum scale. All video generators incorporate a blink frequency generator that allows selective blink.

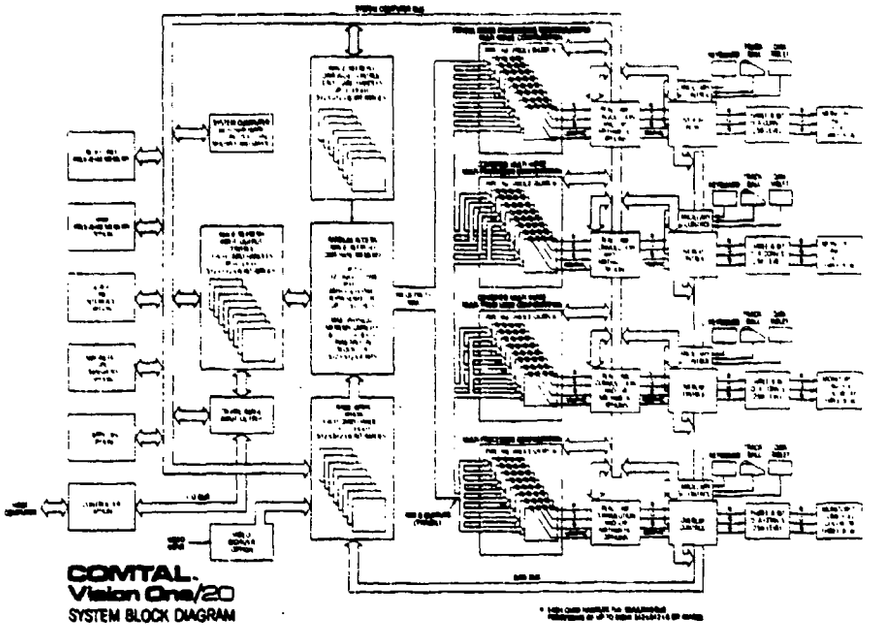
There are three off-the-shelf video generators that satisfy most applications:

A. The Type 1 Video Generator (RM-9400-V1) is designed for general graphics applications. The RM-9400-V1 drives 12 two-bit (4-level) video outputs to 12 monochrome or four RGB color displays. In addition, the RM-9400-V1 provides hardware blink and mixes up to four independent cursors with any of the 12 output channels. Color, intensity, overlay and blink assignment are accomplished by PROM coding. Any of 64 colors or four intensities may be specified.

SYSTEM	CONTACTS
Ramtek 9400	Ken Mullany Boston, Mass. (617)862-7720 Sunnyvale, CA (408)735-4800
IMAGE MEMORY **CONFIGURATIONS AND COSTS**	512 x 512 x 1 plane $ 469 1024 x 1024 x 1 plane $2345 Maximum of 8 planes per chassis (add $2000 for larger chassis)
PROCESSOR (SEE ATTACHED)	Z-80 traffic controller ... not recommended for user programming
MEMORY ACCESS	**ONE PIXEL I/O AFTER INITIALIZATION** 1.12 Ms
REFRESH RATE	(512) 25, 30 Hz 50, 60 Hz (1024) 25, 30 Hz
INTERLACE	2:1 1:1 2:1
HOST	**PDP 11/70** DR11B & C (will also quote Mass bus in future) $2200
INTERFACES	**VAX** Similar
PERIPHERALS	keyboard $1500 tablet $2000 joystick $1400 lightpen $2900 trackball $3000

FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR			
		H	Vector Generator = 16,000 Vectors/sec (50 pixels/vector)
		H	Zoom (2x, 3x, 4x, 5x ... 16x) and scroll
		H	Color table (2) 102 x 16:4 per RGB and 4 monochrome hard copy → Second video board for 8 bits per RGB $6120
		S	Arcs, Circle fill and Polygonfill $ 500
		F	area fill
		F	2D translation, rotation and scaling $ 500
	(S)	H	Viewporting
	(S)	H	Decluttering - increased detail with zoom
	(S)	H	Entity detect into display list and return to host
	(S)	H	Down-load display list board w/list processing $3280 -gives power to directly address image data commands

MONITORS	512 - 60 Hz $3970 1024 - 30 Hz $10,200
NTSC ENCODER	
HARD COPY FACILITY	Poloroid system $12,000 35 mm camera & adapter $4000
COST OF BASIC SYSTEM	with 8 bits per RGB in color table $41,100
DESIRED EXTRAS	keyboard, tablet, joystick, lightpen, polygon filler,
TOTAL COST	2D transformations, download display list processor $53,100
COMMENTS	-Maintenance and training course - 4 weeks in CA $ 1,000 -Upgrade to 1024 requires sync and backplane change, and possibly return to shop $ 2,000



COMTAL.
Vision One/20
SYSTEM BLOCK DIAGRAM

Vision One/20 Technical Specifications

- Displayed spatial resolutions of 512 x 512 or 1024 x 1024, guaranteed to meet or exceed test specifications defined in "Quantitative Evaluation of Soft Copy Displays."
- Up to 512 separate bits can represent each and every picture element in a 512 x 512 display presentation (128 bits per picture elements in a 1024 x 1024 display).
- Up to 114,000,000 bits of image refresh data base memory available in a single 6-foot electrical cabinet
- Every one of the 114,000,000 bits of the refresh memory are read out for display in 1/60 of a second
- Enough image refresh data base memory is available to allow a complete 4096 x 4096 x 8 bit array to be viewed in real-time
- Any one bit of the refresh memory can be randomly addressed and read out in 800 nanoseconds.
- Dynamic assignment of image memory for either the representation of brightness increments of an image or one bit dot map overlays
- Image refresh memory may be arrayed in spatial configurations of 512 x 32,768 or 32,768 x 512 picture elements or any other configuration in a 32,768 x 32,768 space
- Refresh memory configuration assignment completely dynamic and entirely under firmware control
- Full color, high fidelity color presentation (up to 2[24] brightness levels image refresh and display) available in all of the spatial configurations mentioned above
- Full 512 x 512 resolution real-time roam of a large data base is provided in a moving window presentation with no restrictions on the direction or rate of movement of the window presentation across the refresh memory data base
- Zoomed presentation of any 256 x 256 or 128 x 128 picture element area of the refresh memory data base with full window capability as mentioned above
- Loop movie presentations of up to 64 separate 512 x 512 spatial resolution frames, 256 separate frames at 256 x 256 spatial resolution and 1024 separate frames at 128 x 128 spatial resolution. Each frame may have up to 256 brightness levels
- Completely independent use of the refresh memory data base by up to 4 users. Each user supplied with separate keyboard control and independent full color video output
- Allocation of portions of the refresh memory data base dynamically assignable between users
- Refresh memory data base data is loaded completely independent of display presentation (dual-ported construction)
- Complete random addressability to a single picture element
- Automatic block transfer of image data provided with the ability to load sequentially from either side to either side or top to bottom or bottom to top
- Freeze frame transfer of image data synchronously into image memory at rates of 1/30 of a second
- Real-time rewriting of the refresh memory data base on the basis of processing algorithms in the output section of the display
- Iterative re-processing of the refresh stored data through system contained processing algorithms performing true "pipeline" processing of the refresh stored data with each processing step taking 1/30 of a second
- Image combining capabilities on the basis of plus, minus, multiply and divide
- Real-time black and white or full color image composition — allowing the non-destructive super imposition of regular or irregular shaped portions of images one upon the other, with complete freedom of nondestructive translation of the super imposition section in any direction. The resulting composition can be instantly used to form and store an entirely new image

SYSTEM	CONTACTS Harvey Raider
COMTAL Vision One/20	(213)797-1175 Pasadena, CA
IMAGE MEMORY	
CONFIGURATIONS AND COSTS	incremental by 512 x 512 x 8 bit image groups $8,000 to $10,000 maximum of 64 groups • 512 bits per pixel
PROCESSOR (SEE ATTACHED)	Pipeline processor to recompute all picture elements LSI micro to handle user interaction, system response, memory management
MEMORY ACCESS	ONE PIXEL I/O AFTER INITIALIZATION 1.5 Ms (read 900 Ns)
REFRESH RATE	30 Hz 60 Hz
INTERLACE	2:1 1:1
HOST	PDP 11/70 RSX11-M is available. Unibus board & DR11B $3150
INTERFACES	VAX Similar
PERIPHERALS	keyboard trackball data tablet magnetic tape transport floppy disk
FACILITIES H-HARDWARE F-FIRMWARE S-SOFTWARE U-USER/PROCESSOR	High powered image processing facilities - upper range -can roam a 4096 x 4096 x 8 bit array -134,000,000 bits of refresh memory read in 1/60 sec. -animation of 64 512 x 512 x 8 images in memory -real time (1/30 sec) image processing features ↓ (list is available) ↓
MONITORS	19" high quality monitor included
NTSC ENCODER	
HARD COPY FACILITY	
COST OF BASIC SYSTEM	approx. $40,000
DESIRED EXTRAS	Prices from approx. $40,000 to $700,000
TOTAL COST	
COMMENTS	-computer built into system -top-of-the-line for image processing

Appendix B
SURVEY UPDATES

Building 37, Room 509
September 26, 1979

To: V.H. Lucke, Design Graphics Personnel, J.F. Berkery, W.E. Lorensen, J.L. Mundy, R.B. Saltzman

Subject: Update #1
Survey of Color Video Frame Buffer Systems

1. In a resent telephone conversation with Ken Anderson, of the Anderson Report, I found that no further information had been uncovered regarding Seiko's (Tokyo) digital TV display. Rumor had it that Seiko had utilized a 4 x 4 transformation matrix similar to the Evans and Sutherland Picture System II with a 512 x 512 full color frame buffer system.

2. Mr. Anderson did give me a name to contact at DEC in Nashua New Hampshire regarding their rumored 512 x 512 color video frame buffer system. DEC's System Processor is based on 2901 archietecture utilizing a 160 Ns cycle time. The system will act as a device on the Unibus with a parallel interface. The initial system will be able to draw 50,000 vectors (short or inch?) per second, but very few other facilities will be offered and the processor will not be user programable. The initial system will offer a maximum of 4 512 x 512 image memory planes, with a 19 inch color monitor and interface for approximately $14,000. It will be available for shipment around June 1980 and development will continue to improve the system.

Peter Atherton
37-509
8-1693