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A pseudo colour image printing system.

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A PSEUDO COLOUR IMAGE PRINTING SYSTEM

by

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TO

MY PARENTS

WITH FEELINGS BEYOND WORDS

ABSTRACT

A number of image processing techniques have been proposed in the past for various applications. A potentially attractive technique is that of Pseudo Colour Processing.This thesis discusses the advantages and limitations of this technique.It also deals with different transformation functions to convert an achromatic image into a chromatic image.The subjective nature of this process is made evident from the results presented.

This thesis also describes the interface of a Colorplot colour printer to the host computer SEL 32/27,as a part of an image processing system.A broad discussion on the capabilities of the software-package supplied by Cerritos Computer Services Inc., is also provided.

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Chapter I

INTRODUCTION

Image Processing has found a wide range of applications and acceptance in the fields of quality control of manufactured parts, computer aided design,enhancement of satellite pictures,forensic science to name a few.In the field of medicine,it has revolutionised the diagnosis of human body by computer tomography also known as CATSCAN.

The increase in the use of image processing is mainly attributed to the decreasing cost of processing elements,hardware display devices, and the increase in the speed and size of memory systems.In the last decade the use of colour information to enhance visual perception has brought about changes in the analysis of digital images.This thesis addresses the concepts involved in Pseudo Colour processing of digital images and its implementation related to a hard copy display unit.

1.1 IMAGE PROCESSING

Image processing deals with techniques that are implemented on an input image to produce an output image with visually pleasing attributes [1].For example an underexposed picture can be improved by enhancing the contrast, or an image with different levels of illumination can be converted into a binary image with only two levels of illumination. However the conversion of a monochrome image into a colour image through pseudo colour techniques offers better 'viewing' as compared to a normal black and white image.

Any image processing technique can only be initiated after obtaining a digitized image and we often use a two dimensional picture to represent any three dimensional object. The process of digitization involves two other subprocesses which are Sampling and Quantization.The former relates to the selection of a set of points over the field of observation.The latter relates to the number of bits that can be used to represent the resolution.

A video camera is a good tool to scan the image and generate an electrical signal.This signal can then be sampled and quantized by an A/D converter.The speed of the A/D conversion is determined by the nature of the application and the rate of flow of the pictorial data.These factors are critical for real time applications and less critical for other purposes.

The digitized image is stored in the computer as a square matrix the row and the column point to a particular picture element or pixel and the intensity at a point is represented by the gray level value at that point .It is thus possible to state mathematically that the function. g(x,y) represents the intensity of light at a point whose co-ordinates are (x,y) in the two dimensional array.

1.2 DISPLAY DEVICES

It is often necessary to view the result after subjecting an input image to image processing techniques. In the case of hardcopy devices such as a printer the input must be sorted to generate the appropriate commands in the proper order for the motion of the 'Pen'.In the case of modern CRT devices the input image data from the host computer is loaded into the buffer and is displayed on the screen as often as is necessary to create a visual impression [2].

A monochrome display may need three D/A converters,one each for the coordinates of the position (x,y) and one for the brightness or gray level information.In the case of a colour display unit atleast five D/A converters are required,one each for the co-ordinates of the position (x,y) and one each for brightness information of each of the three primary colours.

1.3 PSEUDO COLOUR PROCESSING

A potentially attractive area in the field of image processing is Pseudo Colour Processing.The necessity basically arises due to the fact that a normal human eye can distinguish more shades of colour than shades of gray.It is particularly important in detecting a small fault in a manufactured part or growth of cancer in a tissue.The technique of Pseudo Colour processing allows the user to assign different colours for each shade of gray,this enables the viewer to easily notice the variations of the shades in any image and analyse accordingly.

The colour we perceive in an object is basically the nature of light reflected by it or it is the ability to reflect light of a certain wavelength while absorbing the energy of other wavelengths.Kiver [13] discovered that a variety of colours can be generated by the combination of the three primary colours (or secondary colours).This principle is exploited in all display devices to generate the various colour tones as a combination of each colour component mixed in different proportions.

1.4 IMAGE PROCESSING STATION

A general purpose image processing station though quite sophisticated may be made more attractive by allowing easier operator control. This can be made possible by a Touch Screen which can incorporate a menu-pad for initiating any processing. The touch screen can also be used for controlling the display units by displaying the intermediate and final results either on a monitor or on a printer. It can also be used to initiate the digitizer and if any preprocessing is required, the digitized image can be passed through a Digital Filter.

We can thus conceive of an image processing station to consist of a video camera with a digitizer, a filter unit, a display monitor and/or a printer, an operator's console with a touch screen. All these peripheral devices are linked to a computer system with adequate memory capacity. Fig. 1.1 represents the constituent units of an image processing station.

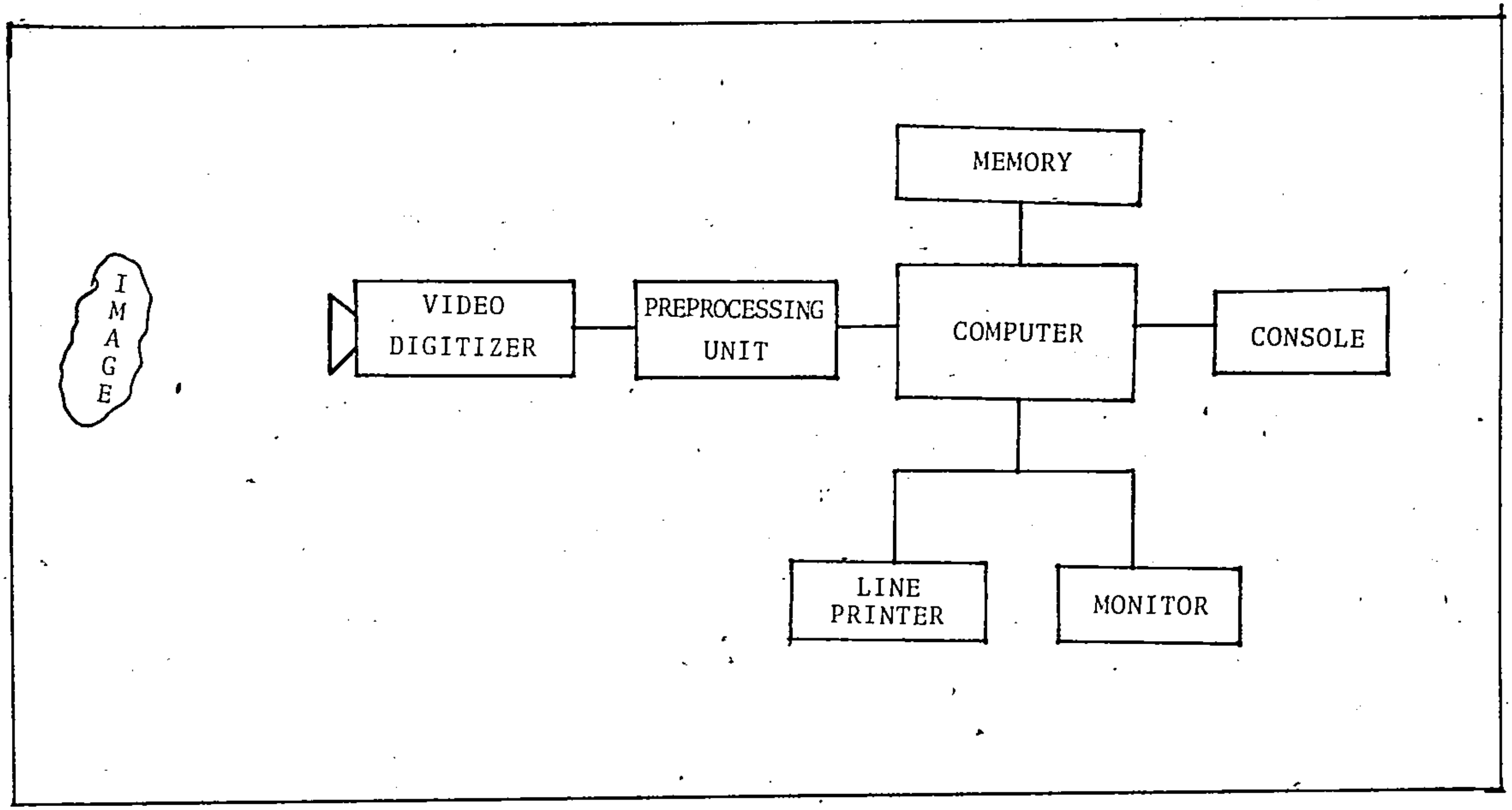


Fig. 1.1 General Purpose Image Processing Station

1.5 OBJECTIVES OF RESEARCH

The objectives of this thesis can be set forth as follows :

1.) Development of interface with the image processing Executive.

2.) Development of driver routines for displaying an image on the printer in colour.

3.) Modify and implement the Triloq software library.

In terms of software requirements these objectives can be interpreted as follows :

i.) Software for interacting with the commands from the touch screen.

ii.) Software for printing a pseudo colour image on the printer.

iii.) Software for generating lookup table for pseudo colour processing.

iv.) Software to obtain a hardcopy of an image from the Aydin colour display unit.

v.) Modification of the Triloq software library.

1.6 THESIS ORGANIZATION

Chapter II gives an outline of the image processing system implemented in the Department of Electrical Engineering and a brief description on each of the peripheral devices.The printer,its working and its interface to the computer, are also described in this chapter.In chapter III the Trilog software package is described and the routines developed based on this package are also explained.In chapter IV some of the fundamentals of pseudo colour processing are illustrated and an algorithm for displaying an image on the printer is explained.In the last chapter a summary of the work done is presented.

Chapter II

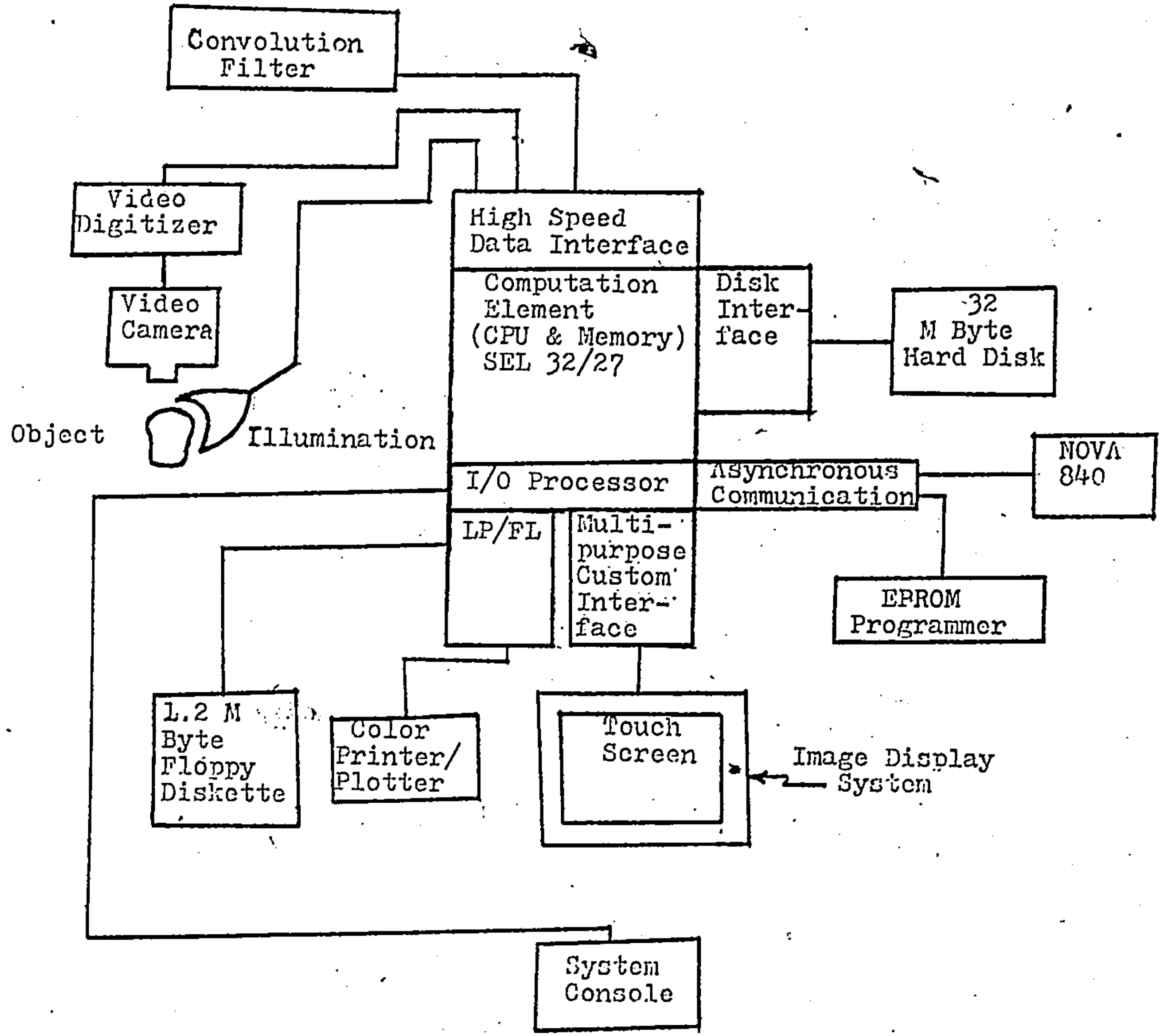
IMAGE PROCESSING SYSTEM AND INTERFACE WITH COLORPLOT

2.1 INTRODUCTION

In this chapter we endeavour to discuss the various peripherals attached to the host computer SEL 32/27,which is dedicated for image processing applications.A brief note on the interface between the Colorplot printer and the host computer is also given. This image processing station with a touch screen mounted on the Aydin colour monitor is aimed to provide touch switch control for the operator.

2.2 IMAGE PROCESSING SYSTEM

The image processing system which is being developed is centered around the host computer SEL 32/27 manufactured by the Systems Engineering Laboratories[3].The image is input to the computer through a Hamamatsu vidicon camera and a digitizer connected to the SEL Bus through the High Speed Data (HSD) interface.Preprocessing of the image is performed by means of the hardware convolver,which is also interfaced to the SEL Bus through the HSD interface,as a peripheral.



Organization of the Image Processing System.

The processed image can be displayed on the Aydin colour Monitor which is interfaced to the I/O processor through the Multi Purpose Custom Interface (MPCI).The hardcopy of the processed image or the intermediate results can be obtained on the Triloq colour printer which is connected to the I/O processor through the Line Printer/ Floppy disk (LP/FD) interface and Multipurpose Bus (MPB). The operator can control the process from the system console connected to the I/O processor and also from the Touch Screen,mounted on the Aydin colour monitor.This system is also connected to the NOVA 840 through the Asynchronous Communications Bus to facilitate data transfer between the two computers.

2.3 HOST COMPUTER-SEL 32/27

The SEL computer is a 32 Bit Mini computer and has 512 Kbytes of MOS memory,32 Mbytes of Hard Disk pack and 1.2 Mbytes Floppy Diskette Drive.It also has an Input/Output Processor,a High Speed Data Interface and a General Purpose Communication Multiplexer.The hard disk pack,HSD and the CPU communicate with the SEL Bus.The I/O processor communicates between the SEL Bus and the MP Bus.To facilitate the development of different processing algorithms a Multi Tasking Executive(MPX-32), FORTRAN 77 compiler and an Assembler have also been incorporated into the system.

The SEL Bus is a high speed 32 bit synchronous Bus capable of transferring data at the rate of 26.67 Mbytes per second and each module connected to the SEL Bus is assigned a unique priority.The multipurpose Bus on the other hand is a medium speed 16 bit asynchronous Bus capable of transferring data at the rate of 1.5 M bytes per second.

2.4 VIDEO DIGITIZER

The video digitizer is used to convert an image into a discrete array of numbers or a digitized image.The signal from the Hamamatsu vidicon camera is sampled and converted into an 8 bit digital data by the A/D converter within the video digitizer.The sampling rate is limited to the rate at which data can be stored in the memory of the SEL computer.The video camera can gather a complete 256 X 256 image in 2 vidicon scans.

The video digitizer is also interfaced to the host computer through the HSD interface along with the convolutional filter.To achieve higher computational speed the filtering and digitizing of the input image can be multiplexed.

2.5 HIGH SPEED CONVOLVER

A dedicated hardware unit for filtering an image results in faster processing and can be used for real time image processing applications. The high speed convolver unit installed can be used for filtering images and for template matching. This filter is based on Number Theoretic hardware techniques and is implemented as a 2-D, radix-2 NTT computational element. The filtering is performed by taking the NTT of the image, multiplying this by the filter impulse response and then taking the inverse NTT of the product.

The filter uses mainly EPROMS, adders, registers and memory buffers, the hardware is organised to compute circular convolution of an 128 X 128 image with 128 X 128 spatial filter kernel. The linear convolution of different sizes of the images and the filter kernels have been implemented via software by using overlap save technique of sectioned convolutions.

The convolutional filter has been interfaced to the SEL 32/27 through the High Speed Data interface. The implementation of the convolution filter via the indirect transform resulted in a low cost, high speed system.

2.6 DISPLAY UNIT - AYDIN 5216

The Aydin 5216 [4] is quite sophisticated and is built around the INTEL 8086 (16 bit) Microprocessor.The firmware provided has an instruction set of alphanumeric and graphic instructions and it does not provide its own operating system.The standard firmware for Aydin is provided on one card and by including another card for the operating system the Aydin 5216 can be used as a stand alone computer.As an alternative to this,the second card may be replaced by the operating system supplied by a host computer.In this configuration the host communicates with the display unit as if it were a peripheral device of the host.

The Aydin 5216 display is interfaced to the SEL 32/27 through a multipurpose custom interface.The standard firmware provided accepts commands from the SEL computer and executes the necessary codes to generate alphanumeric or graphic data.The 5216 has a resolution of 512 X 512 pixels and upto 256 colours can be displayed on the monitor simultaneously.Apart from accepting commands from the SEL computer,the Aydin monitor is also capable of executing commands entered through its keyboard.

The serial interface for the monitor enables data transfer for loading the pixels in the refresh memory of the processor. Individual Red,Green and Blue composite outputs having 8 level intensity provide a total of 256 unique colour combinations.The pseudo colour capability and gray level translation is made possible by a RAM lookup table.

The Aydin colour monitor utilizes the basic television principles to produce a raster scan display.The alphanumeric and graphics data generated is converted into the three colour signals. Synchronisation or sync signals are included with the green signal or as an external sync.The digital data is translated by the display computer into a dot matrix field pattern which in turn is converted into composite video signals for the three colours.

2.7 COLOUR PRINTER

The Trilog Colorplot is a unique colour printer capable of plotting in multicolour or Black & White on a plain paper without any toners [5].It uses a colour ribbon made up of three colour zones Magenta,Cyan and Yellow.The various colours are achieved by interspersing the colour dots and controlling the dot density by software.A typical example would be the the interspering of the yellow and cyan dots to produce a green tone.The shade of green(light or dark) that can be produced depends on the dot density of the two primary colours.

The Trilog Colorplot is programmed to plot all the yellow dots first followed by magenta and cyan.The form is reversed after plotting all the yellow dots and again after plotting all the magenta dots.This arrangement is quite practical and it avoids contamination of colours, especially yellow.

Printing is done by a bank of hammers mounted on a moving shuttle. As the shuttle sweeps across, the hammers are activated electromagnetically at each position at which a dot is to be printed. The shuttle slows down towards the end of the line and accelerates in the reverse direction,the paper feed moves the paper by one vertical dot row.

2.7.1 Character Printing

The upper case characters are printed by the Colorplot as a 7X9 dot matrix.It is possible to plot upto 132 characters per inch. A standard set of 96 ASCII characters is stored in a PROM,and is accessed by the received character codes.The table (2.1) shows the character set.

BITS 4-1	BITS 7-5							
	000	001	010	011	100	101	110	111
0000		Colour Zone 1 Yellow	Space	0	@	P		p
0001		Colour Zone 2 Red	!	1	A	Q	a	q
0010		Colour Zone 3 Blue	"	2	B	R	b	r
0011			#	3	C	S	c	s
0100			$	4	D	T	d	t
0101	PLOT		%	5	E	U	e	u
0110	8 LPI		&	6	F	V	f	v
0111		Reverse	'	7	G	W	g	w
1000	elong. char.		(	8	H	X	h	x
1001	comp. prt.		)	9	I	Y	i	y
1010	line feed		*	:	J	Z	j	z
1011			+	;	K	[	k	{
1100	form feed		,	<	L	\	l	/
1101	carr. rtn.		-	=	M	]	m	}
1110	shift out		.	>	N	^	n	~
1111	shift In		/	?	O	_	o	delete

Table 2.1 STANDARD 96 CHARACTER ASCII SET

2.7.2 Plotting

The plot mode is selected by the PLOT command and by omitting this the printer will continue to be in PRINT mode.In the Plot mode bits 1 through 6 of each data byte are interpreted as six contiguous dot positions in a dot row.The 7th bit is always programmed as '1' to identify the byte as printable data and it is possible to print upto 100 dots/inch.It should be noted here that it is not possible to mix character and plot data,except by reversing the form to perform the second operation.

2.7.3 Colour Plotting

The Colorplot is capable of producing attractive plots in colour.The colours can be programmed by the user .Before beginning to plot in colour the ribbon drive system initializes by moving the ribbon through a colour boundary crossing.The drive then reverses the direction and during the second pass of the ribbon boundary,the colour code is 'read' and the colour zone in front of the print station is determined.The drive then searches for the colour to be printed as specified by the user's program.

When the required colour zone is in front of the print station, printing proceeds according to the programmed dot density. In the case of multi colour plotting the form is reversed to Top of Form after completely plotting one colour. The three primary colours can be specified by the program by their Hex codes.

YELLOW	10H
MAGENTA	11H
CYAN	12H

The colour selection is programmed as a single byte line immediately preceeding the plot data for the first line to be printed in that colour. Since the colours printed are opaque the various colours can only be generated by interspersing the dots of the three primary colours. The shades that can be obtained can be controlled by the dot density.

2.8 TOUCH SCREEN

The Touch Screen is a unique system providing an easy interaction between an untrained person and a sophisticated computer System. Access to different commands and data files is possible by merely touching the corrosponding position on the screen.

The digitizer of the touch screen measures the touch position by measuring the voltage distribution across the conducting film.Two thin transparent films are mounted in front of the CRT but are kept separated by an insulating layer at the edges.When the screen is touched,one conducting layer is forced into the other yielding an output voltage proportional to the touch position.The voltage is then converted to a binary number,combined with similar data from other axis,filtered and formatted into ASCII characters. and is then transmitted serially.

The touch screen when operating in the continuous mode outputs position data continuously as long as the screen is touched.The output is updated approximately 60 times per second.In the initial touch mode the screen outputs data only on the initial touch.The screen must be released before any other output is produced.This feature is exploited for MENU selection as continuous mode is likely to transmit useless data to the host computer.The touch screen can also be used to operate in a fixed array of touch pads.The message format of the data is sent to the host is dependent on the mode selected by the user.

In the existing configuration the touch screen plays a very important role by providing access to the various peripherals.The touch screen here is trained to simulate the executive for the image processing work station.

2.9 LINE PRINTER/FLOPPY DISK CONTROLLER

The Trilog Colorplot is interfaced to the host computer through the I/O Processor [6].The control is provided by the Line Printer/Floppy Disk (LP/FD) controller,which operates at a moderate speed.The LP/FD circuit board is physically plugged into the I/O backpane of the SEL computer.In general the features of the LP/FD controller can be listed as follows :-

1. All control functions are handled by a Z80 Microprocessor.
2. All data transfers are accomplished using Direct Memory Access (DMA) control.
3. It is interfaced to the Multipurpose Bus (MPB) through a General Purpose Instrument Bus (GPIB) Integrated Circuit (IC).
4. Interface to the line printer is through SSI and MSI components,whereas the interface to the Floppy Disk Drive is through a Floppy Disk Controller IC.

Apart from the above mentioned features the controller board has Parity Generator/Checker circuits,Tranceiver circuits for Input/Output (I/O) of data,Programmable Read Only Memories (PROM's) to store control programs and Random Access Memories (RAM's) for data and parameter storage.

The electrical connections to the line printer are via standard line printer cable.The printer uses a DATAPRODUCTS interface cable and the maximum length of such a cable should not exceed 30 feet.All data transfers between the IOP and LP/FD controller are on the MPB lines 0 through 7.The IOP MPB is a medium speed asynchronous Bus which uses a subset of IEEE 488 protocol.It must be noted at this point that no data conversion is performed by the LP/FD controller.

2.9.1 Initialization

The LP/FD controller is initialized during the computer system power ON sequence.During the initialization the LP/FD controller receives an Interface Clear (IFC) signal from the IOP and this causes the MPU to start the program execution from location zero.

2.9.2 Line Printer / Floppy Disk Controller Address

The Line Printer / Floppy Disk controller address is established by means of jumpers,according to the Address

Jumper Table shown in table (2.2).The lower the LP/FD controller's address is,the higher is its priority.The priority of the controller becomes important when the computer is executing a priority polling sequence.In the present configuration in this department,the line printer address is set as '7EF8' and that of the floppy disk controller is set as '7EF0'.

Jumper Pin Number				
Address	5-12	6-11	7-10	8-9
0	Out	Out	Out	Out
1	Out	Out	Out	In
2	Out	Out	In	Out
3	Out	Out	In	In
4	Out	In	Out	Out
5	Out	In	Out	In
6	Out	In	In	Out
7	Out	In	In	In
8	In	Out	Out	Out
9	In	Out	Out	In
A	In	Out	Out	Out
B	In	Out	In	In
C	In	In	Out	Out
D	In	In	Out	In
E	In	In	In	Out
F	In	In	In	In

Table 2.2

LP/FD Controller Address Jumper Table.

2.9.3 Line Printer Commands

The line printer commands are divided into three categories viz.,Control,Write and Sense.After receiving the start I/O (SIO) command the IOP fetches these commands and sends them to the LP/FD controller.The byte transfer count,address and flags remain with IOP,while the LP/FD controller receives the subchannel address from the SIC instruction constant.A brief description of each of the commands is given in the following pages.

2.9.3.1 Control

The line printer control commands allow paper moves to occur without a data transfer instruction.The MPB bits format for line printer control command requires that bits 6 & 7 be set to 1 to define the byte as a control command.Figure (2.2) illustrates the line printer control command format.

M P B							
0/1	0/1	0/1	0/1	0	0/1	1	1
0	1	2	3	4	5	6	7

Fig.2.2 Line Printer Control Command Format.

Bit 5 - Paper Control,when equal to 0,bit 5 indicates that bits 2 & 3 should not be interpreted.

Bit 4 - This bit is always set to 0

Bit 3 & 2 - Skip Count Line Advance.They specify the number of lines that should be skipped,as illustrated in the table below.

Bit 3	Bit 2	Command
0	0	Skip no line (CR)
1	0	Skip 1 line
0	1	Skip 2 lines
1	1	Skip 3 lines

Table 2.3 Skip Line Format.

Bit 1 - TOF.When equal to 1,indicates that the device has advanced to Top of Form.

Bit 0 - Clear line printer buffer.When equal to 1 it indicates that the line printer buffer has been cleared.

The order of the line printer data and command stream embedded in the IOP MPB data stream is unrestricted.The control characters embedded in the data stream are executed by the printer without entering its data buffer.Data products line printer have a maximum data buffer length of 136 bytes,hence the IOP MPB data streams can have a maximum length of 136 bytes between the control characters. These embedded control characters must be the standard ASCII Codes which are recognized by the printer, eq.,Line Feed (LF)=0A H, Form Feed (FF)=0C H and Carriage Return (CR)=0D H.

2.9.3.2 Write

The line printer write command transfers data to the line printer buffer.The MPB bits format for the write command requires that bits 6 & 7 to be set to 0 & 1 respectively.Figure (2.3) illustrates the format for a line printer write command.

M P B							
0/1	0/1	0/1	0/1	0/1	0/1	0	1
0	1	2	3	4	5	6	7

Fig. 2.3 Line Printer Write Command Format.

Bit 5 - Paper Control,.When equal to 0,bit 5 does not allow any automatic insertion of control characters into the data.Instead all control commands must be inserted by the user.When equal to 1 bit 5 allows CR's,LF's and TOF commands to be automatically inserted by the controller as they are defined in the instruction.

Bit 4 - Pre/Post Print.When equal to 0,bit 4 indicates that the line printer is to print data then perform a carriage control operation.The control characters as defined in the instruction are sent to the line printer after the data is sent to the line printer's data buffer.When equal to 1,bit 4 indicates that the line printer is to perform a carriage control operation before it prints the data.The control characters are sent to the printer before the data is sent to the printer's data buffer.In addition a CR command is sent to the line printer after its data buffer is loaded This action causes the data to be printed.

Bits 3 & 2 - Skip Count.These bits specify the number of lines that should be skipped.Table (2.3) specifies the format for this command.

Bit 1 - When equal to 1 indicates Top of Form operation.

Bit 0 - Clear line printer buffer.

2.9.3.3 Sense

The sense command allows the LP/FD controller to determine the status of the printer.There are 8 device status bits viz.,Busy, Status Modifier,Controller End,Attention,Channel End,Device End, Unit check and Unit Exception.The MPB bits format for a line printer sense command requires that bits 0 thru 3 be set to 0,as these bits are not used by the LP/FD controller.The definition of each of the remaining bits is discussed below.

M P B							
0	0	0	0	0/1	0/1	0/1	0/1
0	1	2	3	4	5	6	7

Fig.2.4 Line Printer Sense Data Format.

Bit 4 - Channel End (CE).The channel end condition is caused by the completion of the I/O operation involving data transfers or control information between the device and the IOP.This indicates that the subchannel has become available for use in another operation.

Bit 3 - Device End (DE).The device end condition is caused by the completion of I/O operation at the device.This condition also indicates that the device has become available for another operation.Note that the CE & DE conditions occur simultaneously.

Bit 2 - Unit Check.This condition indicates that an unusual condition was detected,sense data is available and/or the command was terminated.

Bit 1 - Unit Exception.This condition indicates that a Bottom of Form (BOF) condition exists in a Vertical Feed Unit (VFU) line printer.

2.10 FUNCTIONAL DESCRIPTION OF THE LP/FD CONTROLLER

The entire operation of the LP/FD controller is controlled by the Z80 Micro Processor Unit (MPU), figure (2.5) gives a functional description of the controller. The address decode circuits for the I/O devices uses internal address signals to set or reset interrupts and to set up some special conditions required by the LP/FD controller for proper operation. The other signals associated with the address, decode circuit address of the other internal functions of the LP/FD controller. An 8 MHz internal clock circuit generates all the necessary timing signals for the controller. A brief description of the important blocks shown in fig (2.5) is given in the following sections.

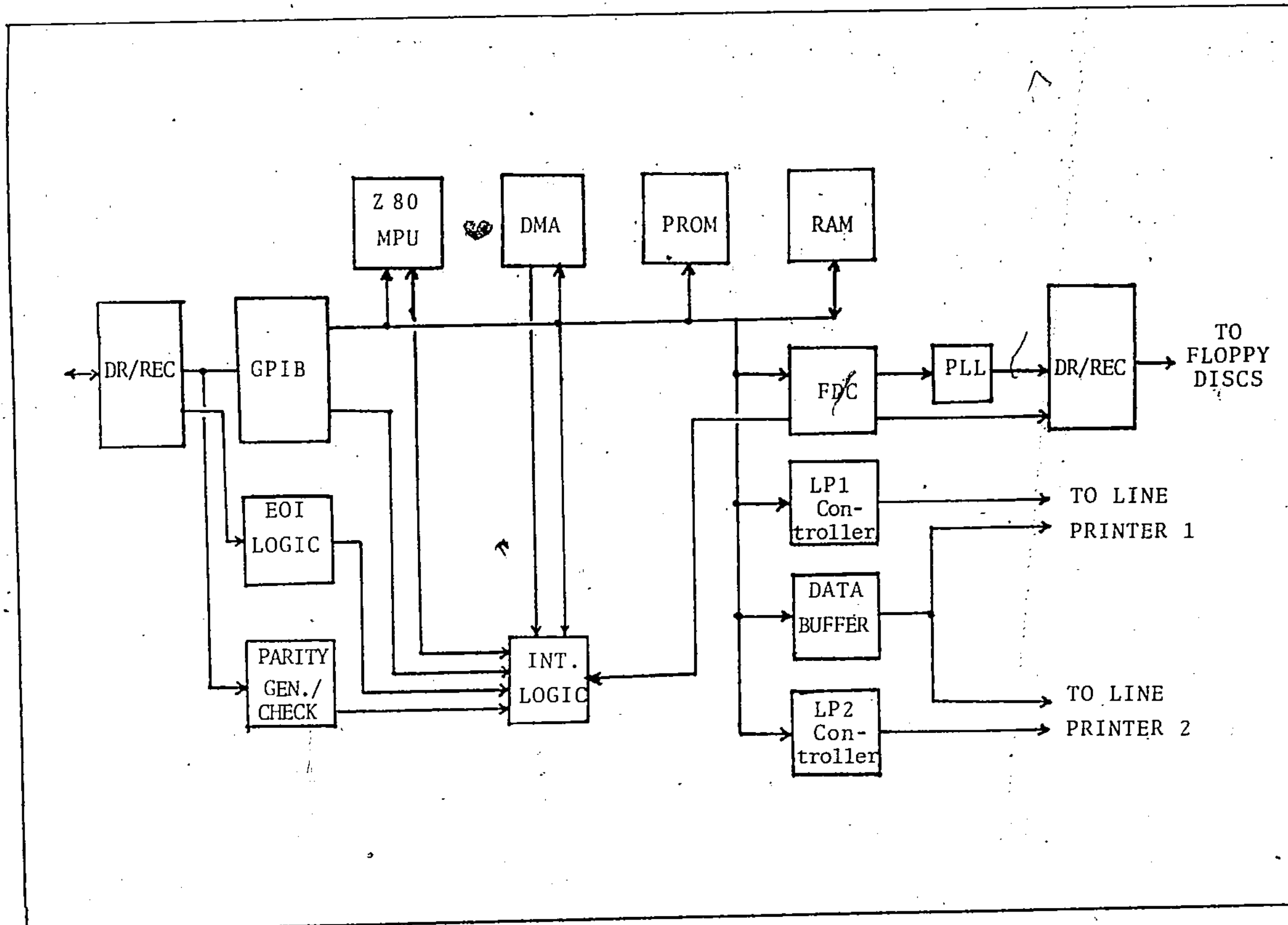


Fig. 2.5 Functional Block Diagram of LP/FD Controller

2.10.1 General Purpose Instrument Bus (GPIB)

The GPIB is used as an interface circuit that connects the LP/PD controller to the Multi Purpose Bus (MPB).The GPIB is controlled by the Z80 MPU and contains the necessary logic to allow information transfers between the MPB and the interface and between the memory and the interface.Data and parity information is also transferred between the MPB and the interface.

The GPIB checks for odd parity during information transfers from the MPB and for generated odd parity during information transfers to the MPB.Bidirectional handshake signals control all the GPIB information transfers.The MPB uses the handshake signals to initiate and effect information transfers.The GPIB initiates information transfers requesting service from the MPB.The MPB then goes through a polling sequence for the service request.The information is then transferred to the MPB using handshake control lines.

2.10.2 Drivers / Receivers

The input driver sends information to the IOP.The input receiver obtains information from the IOP and sends it to the GPIB,EOI logic and parity generate / check circuits,where it is processed and eventually sent to the proper line printer or floppy disk.The output driver sends information to the floppy disk and the output receiver obtains information from the floppy disk and then applies it to the appropriate circuitry within the LP/FD controller for processing.

2.10.3 Interrupt Logic

The interrupt logic generates the interrupt signal and ultimately the vectored interrupt address.The MPU uses the vector interrupt address to locate an interrupt handler to process that particular interrupt.

2.10.4 Parity Generate / Check

The parity generate / check circuit looks for and generates odd parity.The circuit looks at the parity of the data at the trailing edge of the data available line.

2.10.5 Direct Memory Access (DMA) Controller

The DMA controller simultaneously performs either a memory write / port read or a port read /mem ory write.The DMA interrupt channels are as follows : channel 0,Floppy Disk Controller (FDC); channel 1,GPIB;channel 2,Line Printer ~~1~~ (LP1);channel 3, Line Printer 2 (LP2).

2.10.6 Memory

The memory functional blocks comprise five (1k by 8) PROM's and three (1k by 8) RAM chips.The PROM's contain the firmware that controls the operation of the LP/FD controller,the RAM's provide the temporary information storage.

2.10.7 Floppy Disk Controller (FDC)

The FDC supports and is completly compatible with double density and single density formats.It contains 2 registers,Status and Data, which may be accessed by the Z80 MPU.The 8 bit main status register contains information for the Floppy Disk Drive (FDD).Data are only read from the status register and then used to facilitate the transfer of data between the MPU and the FDC through status register.

2.10.8 End or Identify (EOI) Logic

The IOP interface logic enables and disables the receipt and generation of the EOI to the MPB.The purpose of the EOI logic circuit is to handle burst termination.This circuit is the only area where the IOP deviates from the IEEE-488 specifications.The IEEE-488 states that only the talker (sender of data) can terminate the burst,with the EOI logic circuit,both the talker and the listener (receiver of data). can terminate the burst.

2.10.9 Line Printer Controller (LPC)

The LPC can execute formatted and unformatted write operations When performing a formatted write operation the control characters,Carriage Return (CR),Line Feed (LF) and the Form Feed (FF) are included in the data stream as discussed in the previous sections.In an unformatted write operation the control characters are inserted by the line printer on a line by line basis.Details regarding the specific control signals are discussed in length in the section on 'Line Printer Interface'.

2.10.10 Micro Processor Unit (MPU)

The Z80 MPU controls the operation of the LP/FD controller.It accesses the PROM where the firmware programs are stored,using read (RD) signal.It accesses the RAM for temporary storage using both RD and the write (WR) signals.

The Z80 MPU data lines (MDAT) provide 8 bit bidirectional information transfers between the Z80,memory and the Floppy Disk/Line Printers.The address lines access memory locations for memory read/write operations.The MPU also reads information from or writes information to the internal registers. The interrupt (INT) input informs the MPU that an interrupt has occurred and the interrupt vector address is on the MDAT lines. The MPU uses the vector address to locate the interrupt handler, in memory, that will process the particular interrupt that occurred.

2.11 LINE PRINTER INTERFACE

The line printer interface uses two asynchronous handshake lines for proper operation. The Timing diagram shown in fig. (2.6) for a Data Products interface describes the sequence of data transfer.

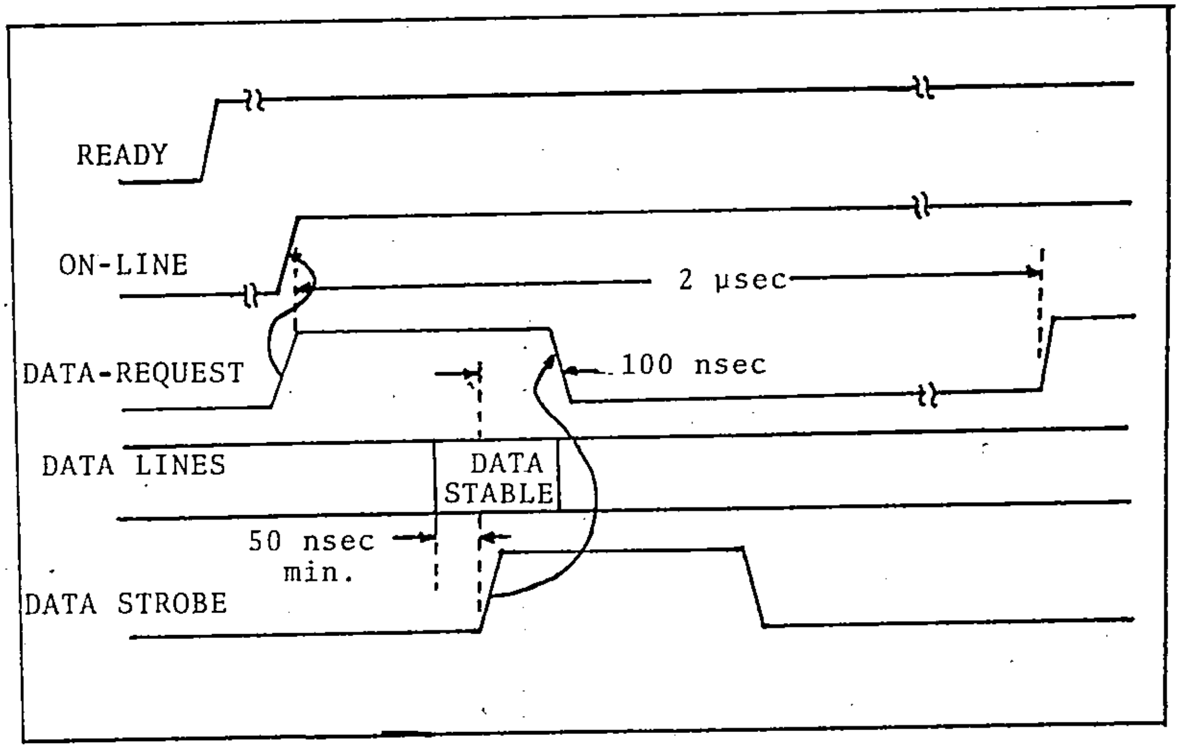


Fig. 2.6 Timing Diagram of Data Products Interface

The Data Demand (HDATADEMAND) line comes from the printer,indicating that it is ready for data.If the HDATADEMAND line is high and the HDATASTROBE line is not set,a DMA request (HDMAREQ) signal is generated [8].

The Data Request (IDR) is sent every 2 micrcseconds by the printer to synchronize with the HDATADEMAND and will remain high until a Data Strobe is received.The Data Request line then goes low within 100 nsec.The Data Strobe (HDATASTROBE) line goes to the line printer indicating that the data is there on its data inputs.This should remain high until IDR goes low.The Data lines must be stable for atleast 50 nsec before Data Strobe is sent.

The Ready (IRDY) signal is sent to the host computer by the line printer to indicate that it is ready to accept data.This signal remains high until a CHECK condition occurs.The Online (IONL) signal goes high,when the ONLINE button is depressed by the operator.The table (2.4) gives the various interface line functions and the corresponding signals for the SEL computer LP/FD controller and the Trilog Colorplot.

SIGNAL	DESCRIPTION	SEL	COLORPLOT
Data Request	Sent by the printer to synchronize data transmission. When true, requests a character. Remains true until Data Strobe is received, then goes false within 100 nsec	HDATADEMAND	IDR
Data Strobe	Sent by user system to cause printer to accept information on data lines. Should remain true until printer drops Data Request line. Data lines must stabilize for atleast 50 nsec before Data Strobe is sent.	HDATASTROBE	IDSTB
Data Bit1	Bit 8 controls optional character set.	HLPD01	IDB1
Data Bit2		HLPD02	IDB2
Data Bit3		HLPD03	IDB3
Data Bit4		HLPD04	IDB4
Data Bit5		HLPD05	IDB5
Data Bit6		HLPD06	IDB6
Data Bit7		HLPD07	IDB7
Data Bit8		HLPD08	IDB8
Ready	Sent to user system by printer. True when no Check condition exists.	HLPREADY	IRDY
On Line	Sent to user system by printer. True when Ready line is true and operator has activated ON LINE pushbutton. Enables interface activity.	HONLINE	IONL
Interface Verify	Jumper in printer connector. Continuity informs user system that connector is properly seated.	LLPCONECTED	ILPCON

Table 2.4

Dataproducts Interface Line Functions.

Chapter III

SOFTWARE PACKAGE - TRILOG LIBRARY

3.1 INTRODUCTION

The software package supplied by Cerritos Computer Services Inc., allows the convenient use of the Colorplot printer as though it were an X-Y plotter.It also enables the user to produce plots in colour or in black and white.Attractive plots and graphics can be generated based on this software package which has been incorporated into the SEL system as Trilog library.It is also possible to vary the size of the plots and the thickness of the 'pen'.

The software package was originally written in FORTRAN IV for a 16 bit machine and this was modified to suit the FORTRAN 77 compiler of the 32 bit SEL machine,existing at this department.In this chapter we will illustrate some of the capabilities of the Trilog library while elaborating on each of the routines.The modifications required for implementing this library are also discussed.

3.2 INSTALLATION OF TRILOG LIBRARY

The software package supplied by Cerritos Computer Services Inc., was on a 1600 BPI tape. As this tape cannot be read directly by the magtape unit in the department, it was copied on to a 800 BPI tape. The tape was unlabelled and contained blocked ASCII records. The files on the tape were then read into the NOVA computer and subsequently transferred via the asynchronous communication Bus of the SEL to the hard disk unit or the SEL Bus. The package has three files as given below.

File 1 : Plot Subroutine Library.
File 2 : Raster Scan Conversion Program.
File 3 : Demonstration Program.

These source files which were meant for a 16 Bit machine were modified to suit the SEL computer (32 Bit).

3.3 CAPABILITIES OF TRILOG LIBRARY

As stated earlier a variety of plots and graphics can be produced based on the software package. This package allows the user to generate the following in different combinations to suit his needs [9].

1.) Labelled and annotated axes.

2.) Textual or character string data.

3.) Graphs from data arrays of X and Y coordinates.

4.) Individual points and vectors.

5.) Shaded or filled polygonal areas.

It should be noted here that the physical X axis runs vertically down and the Y axis runs horizontally across the page.All angles are measured counter clockwise from the physical plotter X axis.The user can also exercise control over the following to produce attractive plots.

1.) 'Pen' motion,width and colour.

2.) Origin of the plots.

3.) Independent offset and scale for the data arrays.

4.) Rotation and size of text and axes.

5.) Density and pattern for shaded areas.

3.4 LOGIC FLOW FOR PRODUCING PLOTS

The user can produce any plot by compiling and executing the program which has calls to the plot subroutines.The output of the user's program is a file of intermediate pen motion commands This file of pen motion commands is linked to the raster scan conversion program to produce a file of raster data.The raster data also includes the paper motion control information,colour change information and 'pen' width information.The file containing the raster data is then linked to the driver routine which transfers the data to the printer buffer and which in turn activates the 'pen' to produce the desired plot.

In the case of multicolour plots the data for yellow colour is transferred first and after the plot for yellow is produced the form is reversed and the data for magenta is sent to the printer buffer.After plotting the magenta colour the form is reversed again and the data for cyan colour is transferred from the host computer to the printer buffer.The flow chart illustrated in fig 3.1 shows the logic flow.

Figures 3.2 and 3.3 illustrate a line plot and a multiple plot that was produced by utilizing the capabilities of the Trilog library.The software developed for producing such plots can be programmed by the user for single or multiple plots.

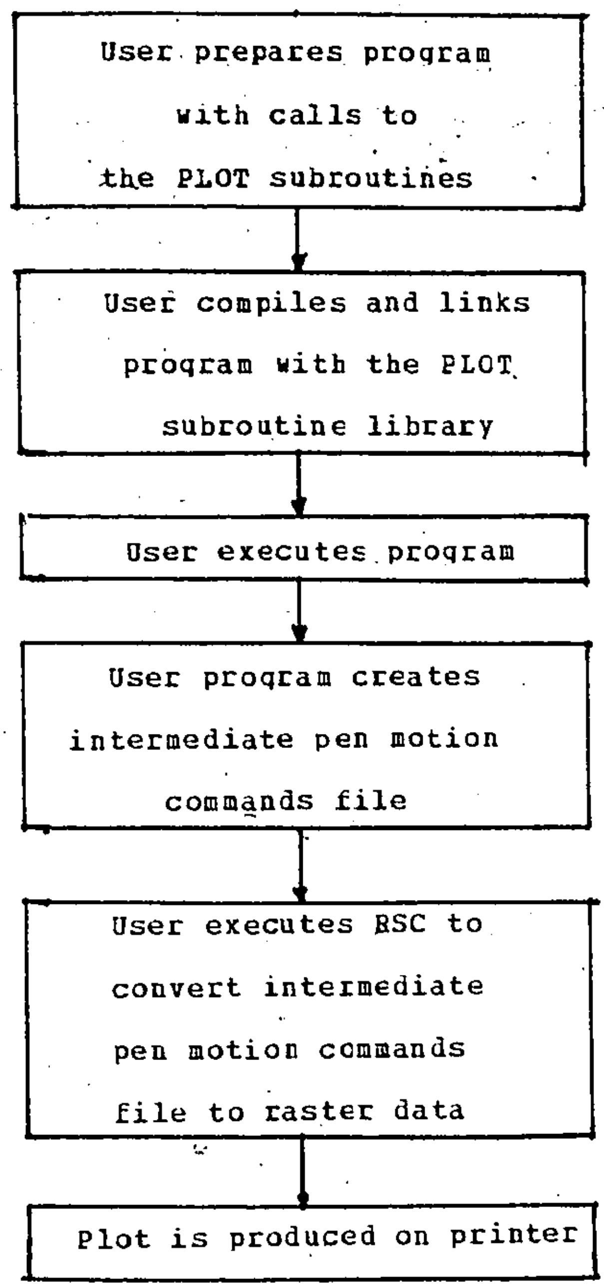


Fig. 3.1 LOGIC FLOW TO PRODUCE PLOTS

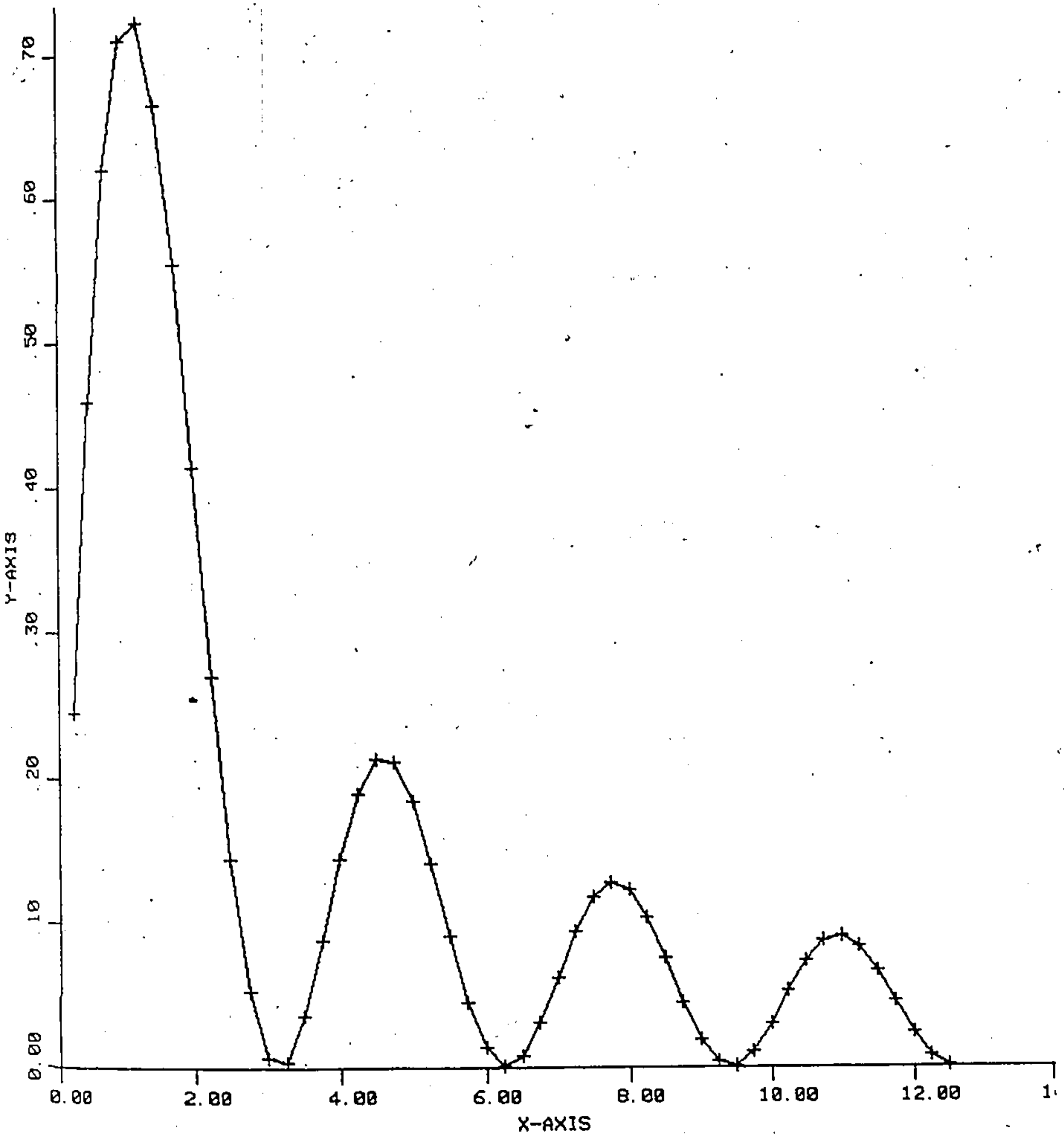


Fig. 3.2 Line plot produced by the printer.

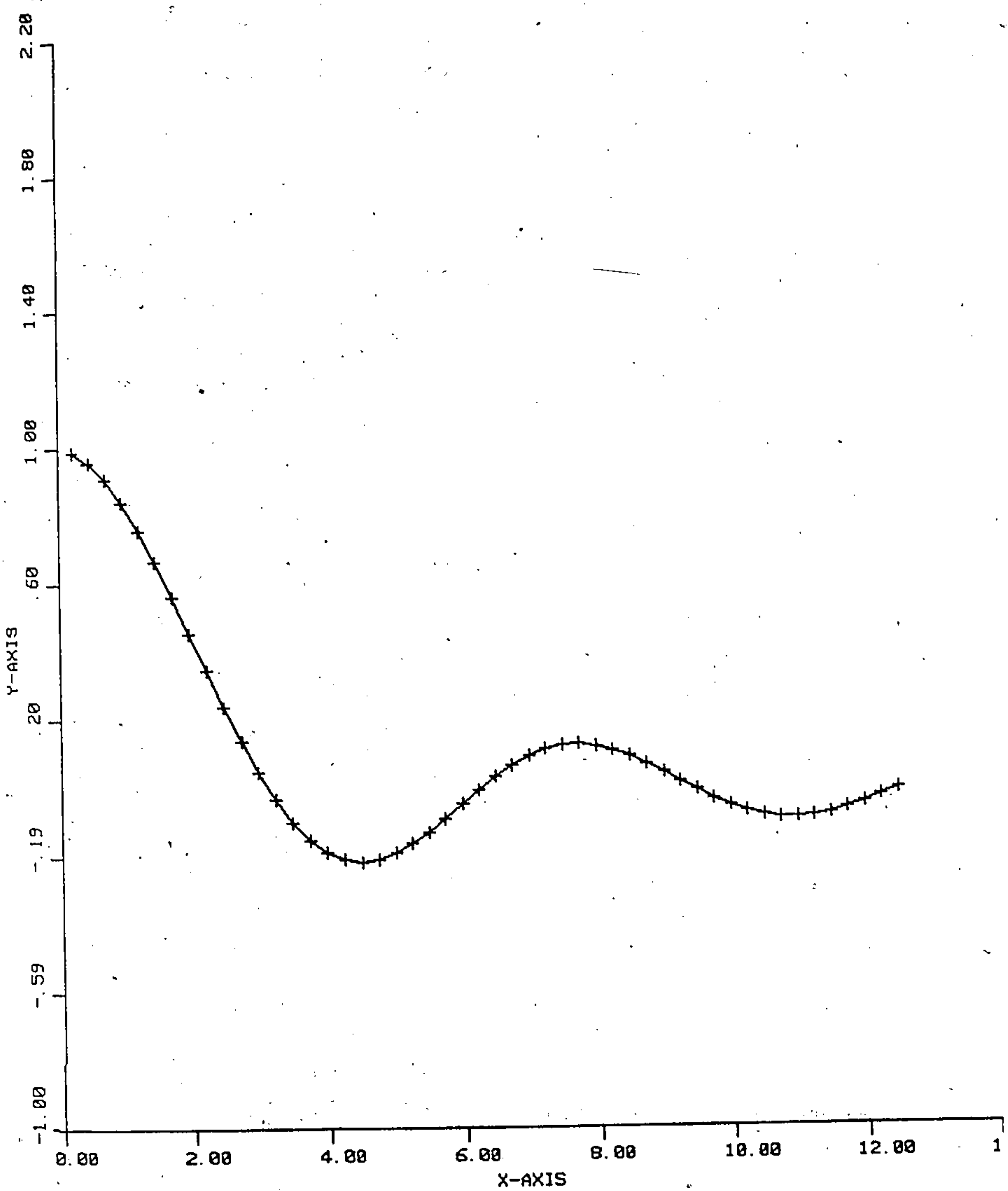


Fig. 3.3 Multiple plot produced by the printer.

3.5 SUBROUTINE LIBRARY

This was created by compiling the subroutines of file 1 to form object files.The library is linked with the user program to form an executable program.When the user program is executed it creates a file of intermediate pen motion commands.Labelled COMMON statements in FORTRAN are used to pass all the internal data between the various plot routines.

3.6 COMPONENTS OF TRILOG LIBRARY

In this section we will be describing each of the components of the subroutine library briefly[10].All the lengths,heights and sizes are in plotter units and the default value is 1 plotter unit equal to 1 inch.The plotter resolution is ofcourse limited to the size of the dot.The physical plotter origin is initially at the top left of the printer page.The calling sequence for each of the routines is given in the Appendix.

3.6.1 Subroutine PLOTS

This is a very important routine as it initializes all the other routines in the library to begin any plot.It also sets the scale factor to its default value (1 inch = 1 plotter unit) and this can be changed by the user program.The initial 'pen' location or origin is set to (0.0,0.0).It should also be noted that this is to be called once and only once by the user program.Subsequent calls to reinitialize will result in error.

3.6.2 Subroutine PLOT

It is often required by the user to begin the plots at an origin away from (x,y)=(0.0,0.0).To facilitate the plotting at a desired origin the calls to the subroutine 'PLOT' will result in the shifting of origin as given by the user's program.This routine is also capable of drawing a vector from current 'pen' position to a new 'pen' position.Pagination control can also be exercised by the user .The PLOT routine can operate in any of the following 3 modes :-

a.) The Draw mode causes a line to be plotted from current 'pen' position to new 'pen' position.

b.) The Move mode causes the 'pen' to move from current position to new position without plotting a line.

c.) The Erase mode is rather unique and it causes the 'pen' to move from a current position to a new position erasing any line already plotted.

Once the origin of the plot is set all the 'pen' motions are calculated with respect to this origin.It is also very important to terminate all plot programs properly to avoid erraneous data to be written into the pen motion commands file.

3.6.3 Subroutine FACTOR

FACTOR allows altering the scale factor for plot size from the default value of 1 plotter unit equal to 1 inch .Multiple calls to this routine are cumulative and a factor of 1.0 resets the scale to the default value.

3.6.4 Subroutine WHERE

This routine can be used by the user to determine the current 'pen' position and the scale factor.A call to this routine returns the coordinates (x,y) and the scale factor to the user's program.This allows the user to program the plots not to exceed set limits.

3.6.5 Subroutine SYMBOL

SYMBOL plots character or textual data at a desired position and angle.The appearance of the symbol is dependent on the resolution of the printer.

3.6.6 Subroutine NUMBER

This routine plots floating point data as a numeric character string in a format similar to FORTRAN F format.This routine also allows user control over height,pen width,pen position,and the angle desired.The numbers plotted are truncated and not rounded off.

3.6.7 Subroutine SCALE

It is quite necessary to calculate the scaling offset and scaling increment to plot any data,the routine SCALE serves this purpose quite efficiently.This routine is also called by two other routines in the library,AXIS and LINE,and returns the scaling offset and scaling increment to the user's program.SCALE does no plotting of its own and does not modify the data in the array.Two extra locations should be provided in each of the data arrays before calling this routine to accomodate the values for scaling offset and scaling increment.

3.6.8 Subroutine AXIS

This routine produces an axis with labelled tic marks which are one plotter unit apart.It is also possible to plot a title centered on the axis.The angle,length and position of the axis can be controlled by the user.The annotation values plotted for the tic marks depend on the scaling offset and scaling increment and not on the coordinate system or overall scale factor.The coordinate of the plotted point may be completely independent of the annotation system used with an axis.

3.6.9 Subroutine LINE

LINE combines pairs of data points in two arrays and plots the points sequentially to form a line according to user specified parameters.Points can be plotted with an optional special symbol and an optional connecting line between points.The offset and scaling of the points to fit the line are calculated automatically by the routine SCALE.The values returned by the SCALE are used to calculate the x and y coordinates as given by the equation below.

$$x = (x - xoffset/xincrement)$$
$$y = (y - yoffset/yincrement)$$

The user must provide at least two extra locations in each array for the scaling offset and scaling increment.

3.6.10 Subroutine NEWPEN

NEWPEN is very useful in setting the 'pen' width and/or 'pen' colour, in the case of multicolour plots. It can be called any number of times and the thickness and colour can be changed for each call.

3.6.11 Subroutine NEWMSK

It is useful in providing control over the dot patern used to generate lines . The mask control word given as an integer is converted into a 16 bit binary number by the program and plots the dots corresponding to the 1 bits of the word. For example a word of 257 results in every eigth dot being plotted. The default value is set to -1 to allow every dot to be plotted.

3.6.12 Subroutine SHADE

This routine allows any area to be shaded with equally spaced lines at any given angle. If the area is not closed, then the first and last points are joined to form a closed area. The mask control word supplied by the user affects only the lines shading the area and not the outline. The scaling offset and scaling increment are returned by the routine SCALE.

3.7 DEVICE DRIVERS

A device driver is the operating system interface between the user program,the operating system and the hardware that controls the device.The Colorplot printer can operate with a line printer driver. The only restriction is that the device driver and operating system must pass the plot mode control characters and raster characters without conversion.

3.8 RASTER SCAN CONVERTER

The intermediate file of the pen motion commands contains important information which has to be converted into Raster data to produce plots on the printer.The raster data has the 'pen' width,cclour change and paper motion control information.

The raster scan conversion program initializes the values for the band height,width,dots/inch,resolution and other parameters.It then opens the intermediate pen motion commands file and also the device.A new page is forced before producing any plot and the input from the intermediate file is converted into an output scratch file by the program.The output scratch file is then used by another subroutine which is converted into file of raster data.This file of raster data has all the control information required to produce a plot as desired by the user.

The raster data is finally linked with the driver subroutine which transfers the raster data as a single byte to the printer buffer.The software driver also sets the 7th bit as a '1' in plot data to identify the byte as 6 contiguous discrete dot positions to be printed.

3.9 MODIFICATIONS TO TRILOG LIBRARY

The software package supplied by Cerritos Computer Services Inc. was written for a 16 bit machine and necessary changes had to be made to implement it on a 32 bit machine [7].One of the major changes was restricting the width of all the integer values to 2 bytes.The statement IMPLICIT INTEGER*2 (I-N) defines all the integer values as 2 bytes wide.The Logic Unit(LU) is 4 bytes wide and hence has to be defined separately as INTEGER*4 LU.

The raster scan conversion program was developed for a Printronix printer and some of the variables have to be changed to suit the Trilog Colorplot.The band width was changed from 64 to 110,the band length from 4096 to 7040,the nomber of dots/inch in X direction from 60 to 100 and the number of dots in Y direction from 60 to 100 dots/inch.The Printronix printer is not capable of plotting in colour,whereas the Colorplot can be programmed to produce attractive plots in colour.Hence the colour enable was set to one in the routine which initializes the raster scan program.

A subroutine to extract characters from an array containing character data was developed as a part of the Trilog library. The characters are extracted from a standard ASCII look up table and returned to the user's program.A device driver routine was also developed to transfer the raster data to the printer buffer.The subroutine PLOTLINE is capable of transferring the control signals like reverse form feed,change color etc., it is also capable of transferring upto 132 bytes of character data per line.The seventh bit in each data byte is set as 1 by the subroutine to identify the byte as printable data.

The raster scan converter was also modified to insert the control characters into the data stream to perform operations like form feed,reverse feed etc..It was also found that when a text string of ASCII characters was specified directly the compiler failed to recognise them.To overcome this problem the text string was stored in a real array.

For example the string 'X-AXIS' can be stored as RDATA(1)='X-AX' and RDATA(2)='IS ',where RDATA is declared as REAL RDATA(2). The demcnstration program is capable of plotting a spiral or a polygon,no significant changes were required in this program to produce the desired plot.

Chapter IV

PSEUDO COLOUR PROCESSING

4.1 INTRODUCTION

The display of a monochrome or black and white image may not convey the entire information with regard to a particular scene under observation. It is due to the fact that the human visual system is not sensitive to changes in the shades of gray levels. It is for this reason, pseudo colour techniques are utilized to display monochrome image to enhance the visual perception of the displayed image.

In this chapter a brief discussion on the psychophysics of human vision, histogram modification and image enhancement is presented. These discussions are followed by an introduction to pseudo colour fundamentals as well as an algorithm for printing pseudo colour images. Finally a description of some of the techniques adapted to generate colour lookup table is provided.

4.2 PSYCOPHYSICS OF HUMAN VISION

A primary characteristic of human vision is its ability to adapt to a wide variety of ambient scene conditions. In addition to visual sensitivity in the retina, the coded visual information which is transmitted along the optic nerve to the brain, adapts to certain scene characteristics which remain stable over time so that stimulus variations are primarily transmitted [14]. This adaptive behaviour presents a fundamental difficulty in the analysis and modelling of vision.

Indeed a model for the human eye could be used to develop a channel between the computer image and the human vision system. Thus a symbiotic relationship can be developed between the two , that holds promise of advancement of both areas. Work is limited in this area but through a number of experiments it was established [12] that a colour image seemed to provide a pleasing 'viewing'. In the case of monochrome images it was prooved [1] that as many shades of gray as is possible should be used to display an image to achieve high fidelity.

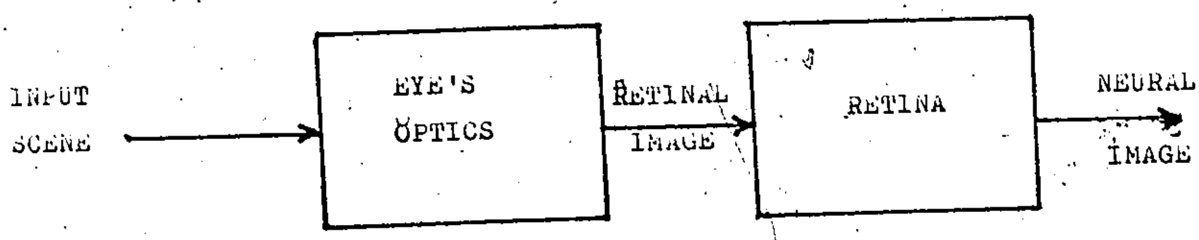


Fig. 4.1 PSYCHOPHYSICS OF HUMAN VISION.

4.3 IMAGE ENHANCEMENT

The computer can be used to 'improve' the quality of an image without recourse to knowledge of degrading phenomenon, resulting in the concept of image enhancement [11]. Both mathematical and heuristic techniques are utilized in this process for extraction of information that may not be so readily apparant in the preenhanced original image.

A histogram of gray level content provides a global description of the appearance of the image [1]. Let the variable r represent the gray level of the pixels and lies in the range $0 \leqslant r \leqslant 1$, where 0 and 1 represent black and white respectively in the normalized range of pixel values. Then the transformation $s = T(r)$ will produce a level s for every pixel value r in the original image. However the transformation $s = T(r)$ has to satisfy the following conditions :

a.) $T(r)$ is single valued and monotonically increasing in the interval $0 \leqslant r \leqslant 1$.

b.) $0 \leqslant T(r) \leqslant 1$ for $0 \leqslant r \leqslant 1$.

Here the first condition preserves the order from black to white in the gray scale and the second condition ensures a mapping that is consistant with the allowed range of pixel values.

A relatively recent development in digital image processing is the use of pseudo colour for image enhancement.The basic principle involved in pseudo colour techniques is assigning a colour to a pixel based on its intensity.In other words the histogram of the original image is modified in such a way that each level in the modified histogram represents a particular colour.By changing the transformation function a wide variety of pseudo colour images can be produced.

4.4 PSEUDO COLOUR PROCESSING

Virtually all research in digital image processing has involved only monochrome images.The human eye ,however,perceives colour as well as brightness information and it is evident that processing techniques should include colour images as well.Smith [12] concluded from his experiments that an object which seemed relatively inconspicuous in a group , on a monochrome display became more apparent when all the objects were colour coded and displayed on a colour monitor.As an extension to this observation,we can state that pseudo colour techniques can increase the discriminability among items or areas in an image.

Basically the colour we perceive in an object are determined by the nature of light reflected from the object.It has been suggested by Kiver [13] that a wide-range of colours can be produced as combination of the three primary colours.However it is important to differentiate between the primary colours of light and the primary colours of pigments.In the case of pigments the primary colours are subtractive that is,one primary colour is absorbed and reflects the other two, the primary colours are additive in the case of lights.

In the area of pseudo colour processing the range of colours that can be generated depend largely on the nature of the display system. The Colorplot printer can be programmed to produce 64 different shades for a pixel represented as a 6 X 6 dot matrix.On the other hand the Aydin display system is capable of generating 256 shades of colours.

Pseudo colour techniques are initiated by taking an achromatic image and mapping it into a tristimulus colour space in which different pixels have different colours upon display.The utility of such a mapping varies in an adhoc manner with the application For example,if a thermal scan of a person is displayed with the warmer regions depicted in shades of red and cooler regions in shades of blue ,there will be compatability between the displayed image and our psychological notion regarding 'warm' and cool' colours.the conversion of an achromatic image into a chromatic image can be done in two possible ways.

1.) Intensity slicing.

2.) Gray level to colour transformation.

4.4.1 Intensity Slicing

This technique of generating pseudo colour images is rather simple and is seldom implemented in practice.In this technique a 'plane' is chosen and all the levels above this threshold are assigned a particular colour and those below are assigned a different colour. The selection of the threshold may be arbitrary and the result of this scheme is a two colour image whose relative appearance can be controlled by moving the plane.

Figure (4.2) represents the mapping function for this technique.A more generalised approach is discussed in the next section.

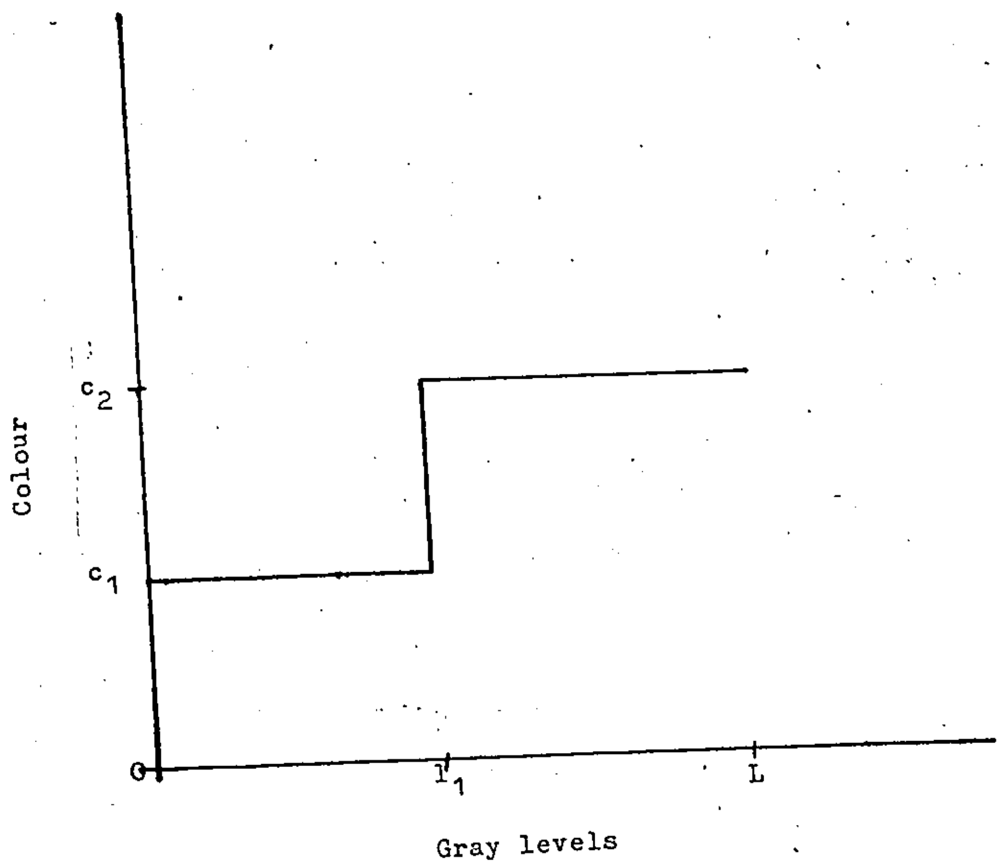


Fig.4.2 Representation of intensity slicing method.

4.4.2 Gray Level to Colour Transformation

This technique is more general and is capable of producing a wider range of pseudo colour enhancement results. From our knowledge that any colour can be produced as a combination of the three primary colours, we can represent an image by 3 colour matrices given as $I_1(x,y)$, $I_2(x,y)$ and $I_3(x,y)$. The subscripts 1,2 and 3 represent the three primary colours, based on the nature of the display system, the variables x and y represent the coordinates of the pixel.

The input image is subjected to three transformations for each of the primary colours and the results are then combined to produce a composite image whose colour content is modulated by the nature of the transformation function. It must be noted that these transformations are based on the graylevel values of an image and are position invariant. A functional block diagram to illustrate this technique is given in fig. (4.3).

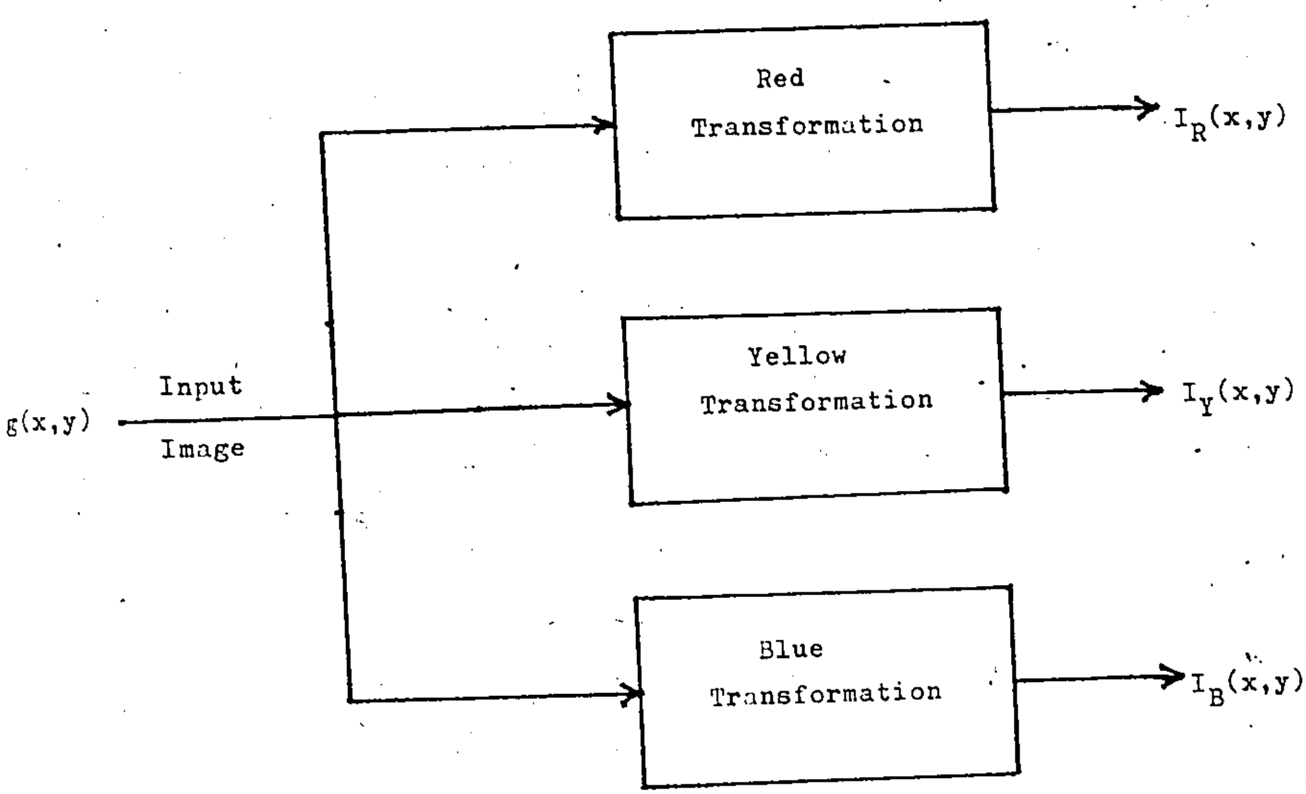


Fig.4.3 Functional block diagram for pseudo colour processing.

4.5 AN ALGORITHM FOR DISPLAYING AN IMAGE ON COLORPLOT

This algorithm is based on the gray level to colour transformation technique and it can be stated as follows :

1.) Read the input image.
2.) Map the gray levels of the original image into 64 levels.
3.) Link a lookup table for each of the three primary colours.
4.) Force a new page before proceeding to plot.
5.) Print the yellow colour followed by magenta and cyan colours. Reverse the form after each colour is plotted completely.

In the implementation of the second step of this algorithm, the limitation imposed is due to the fact that the printer can only produce 64 different shades. The generation of lookup table is quite vital in terms of 'viewing' the processed image. The transformation for each of the primary colours is implemented in an adhoc manner and the results obtained are interpreted and suitable changes are incorporated. This process even though appears to be arbitrary, is perhaps the only simple guideline since visual interpretation of image quality is a highly subjective process.

4.5.1 Algorithm for printing a 256 X 256 Image

The printer is capable of printing images of size 128 X 128,this is due to the physical limitation imposed by the device.However images with a larger size can be printed as multiple blocks of 128 X 128 pels.An algorithm for printing a 256 X 256 image is illustrated in the following steps.

1.) Read the input image
2.) Select the first block of 128 X 128 pixels.
3.) Map the gray levels onto a scale of 64 levels.
4.) Link a lookup table for generating pseudo colour.
5.) Force a new page before proceeding to print.
6.) Print yellow colour first ,followed by magenta and cyan colours.Reverse the form after printing each colour.
7.) Traversing the image clockwise select the next block of 128 X 128 pels.
8.) Repeat steps 3 through 7 until the entire image is printed.

4.6 GENERATION OF LOOKUP TABLE

The Colorplot can be programmed to print six discrete dots for each data byte provided the 7th bit is set to '1'.Thus it is possible to achieve 2**6 or 64 combinations of dots and nodots. In the case of multicolour plotting this can be interpreted as 64 different shades of colours.

4.6.1 Transformation Based on Integer Value

One of the simplest techniques that could be implemented for generating a lookup table is assiging two bits in a data byte for each of the three primary colours. In order to distribute the dots uniformly the colour bits are shifted by two bit positions after every two dots rows. An algorithm for this technique is illustrated in the following steps.

1.) Read pixel value or gray level intensity.
2.) Assign least significant 2 bits to cyan colour.
3.) Assign bits 2 & 3 to yellow colour.
4.) Assign bits 4 & 5 to magenta colour.
5.) Shift the 2 X 2 colour matrix to the right in a cyclic order.
6.) Repeat steps 1 through 5 for the entire image.

Figure (4.4) shows a sample matrix for a gray level intensity of 63. It can be seen that all the three colours are distributed uniformly.

C	C	Y	Y	M	M
C	C	Y	Y	M	M
M	M	C	C	Y	Y
M	M	C	C	Y	Y
Y	Y	M	M	C	C
Y	Y	M	M	C	C

Fig. 4.4 Colour pixel representation for a gray level value of 63 by Bit Assignment method.

Y - Yellow
C - Cyan
M - Magenta

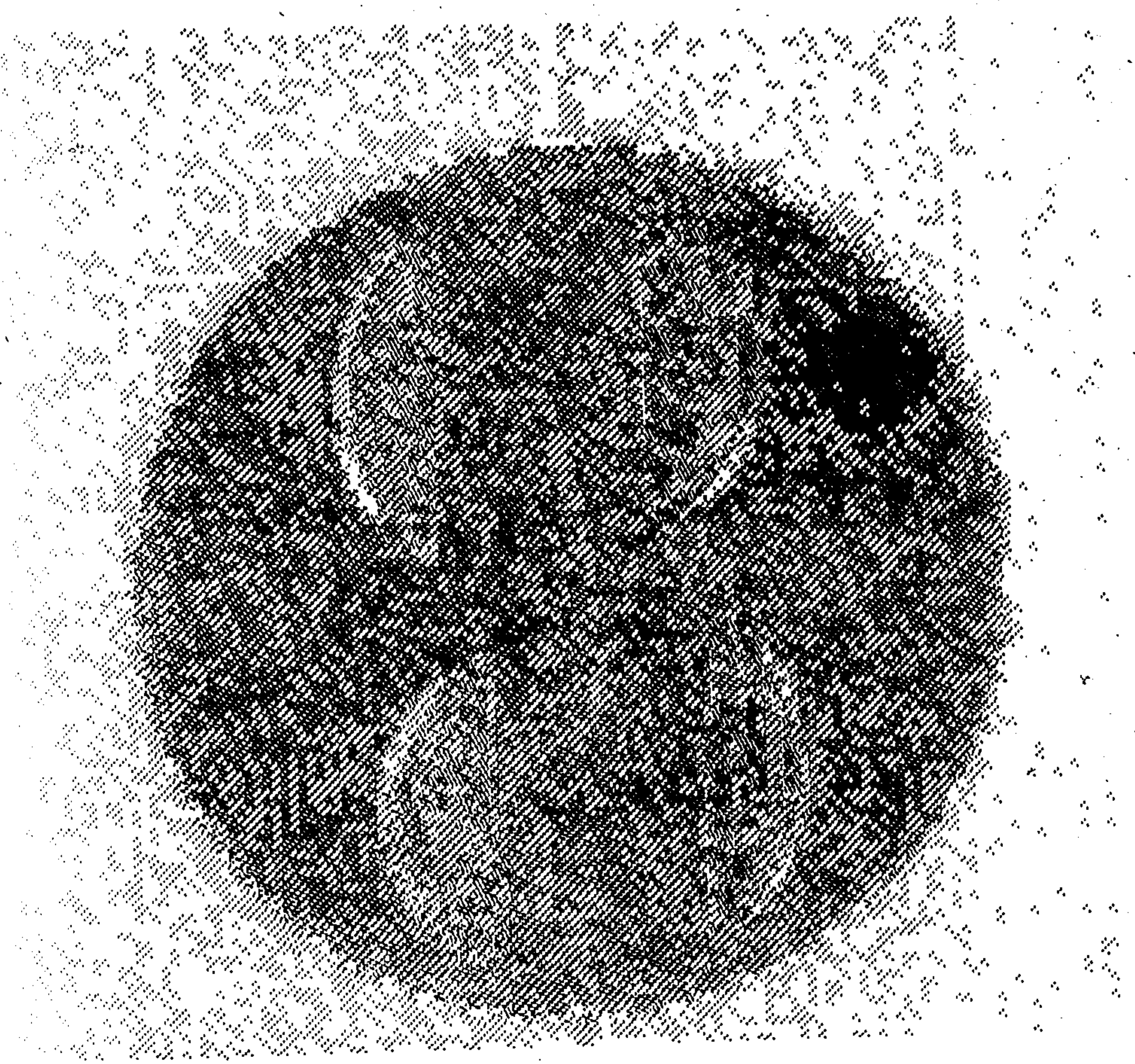


Fig. 4.5 Pseudo Colour by Bit Assignment Method.

4.6.2 Triangular Transformation

The technique discussed in the previous section cannot be used to print a pixel in any of the three pure primary colours. In this section a linear transformation for each of the three primary colours is considered. The pure primaries occur at the end and at the center. The lower half in the gray scale has an increasing yellow content and a decreasing cyan content, the magenta colour being absent. In the upper half the cyan colour is eliminated and the yellow colour is gradually decreased as the red colour is increased. This technique has produced better results than the previous technique, but only a few shades could be distinguished. Fig. (4.7) represents the dot matrix for a pixel value of 21. The following steps illustrate the implementation of this technique.

1.) Read the pixel value from an input image.
2.) If greater than 32 go to step 5.
3.) Determine the values for cyan and yellow based on the transformation shown in fig. (4.6).
4.) Go to step 6.
5.) Determine the values for magenta and yellow colours based on the transformation shown in fig. (4.6).
6.) Repeat steps 1 through 5 for the entire image.

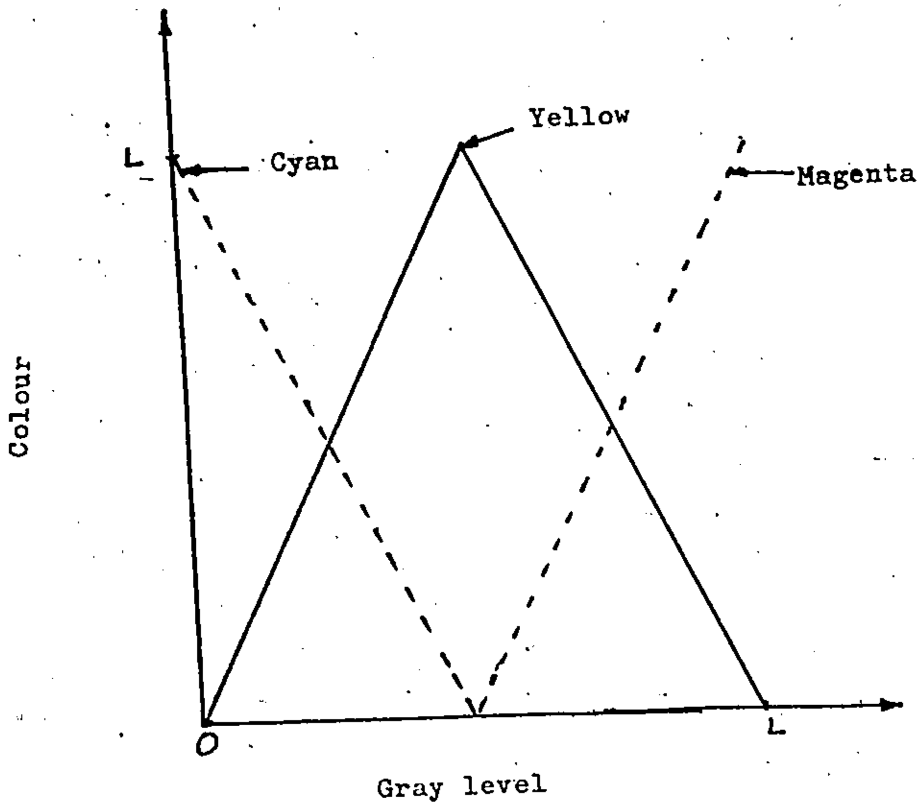


Fig.4.6 Representation of Triangular Transformation.

Y	C	Y	C	C	Y
Y	C	Y	C	C	Y
Y	C	Y	C	C	Y
Y	C	Y	C	C	Y
Y	C	Y	C	C	Y
Y	C	Y	C	C	Y

Fig. 4.7 Colour pixel representation for a gray level value of 21 by Triangular Transformation.

Y - Yellow

B - Blue

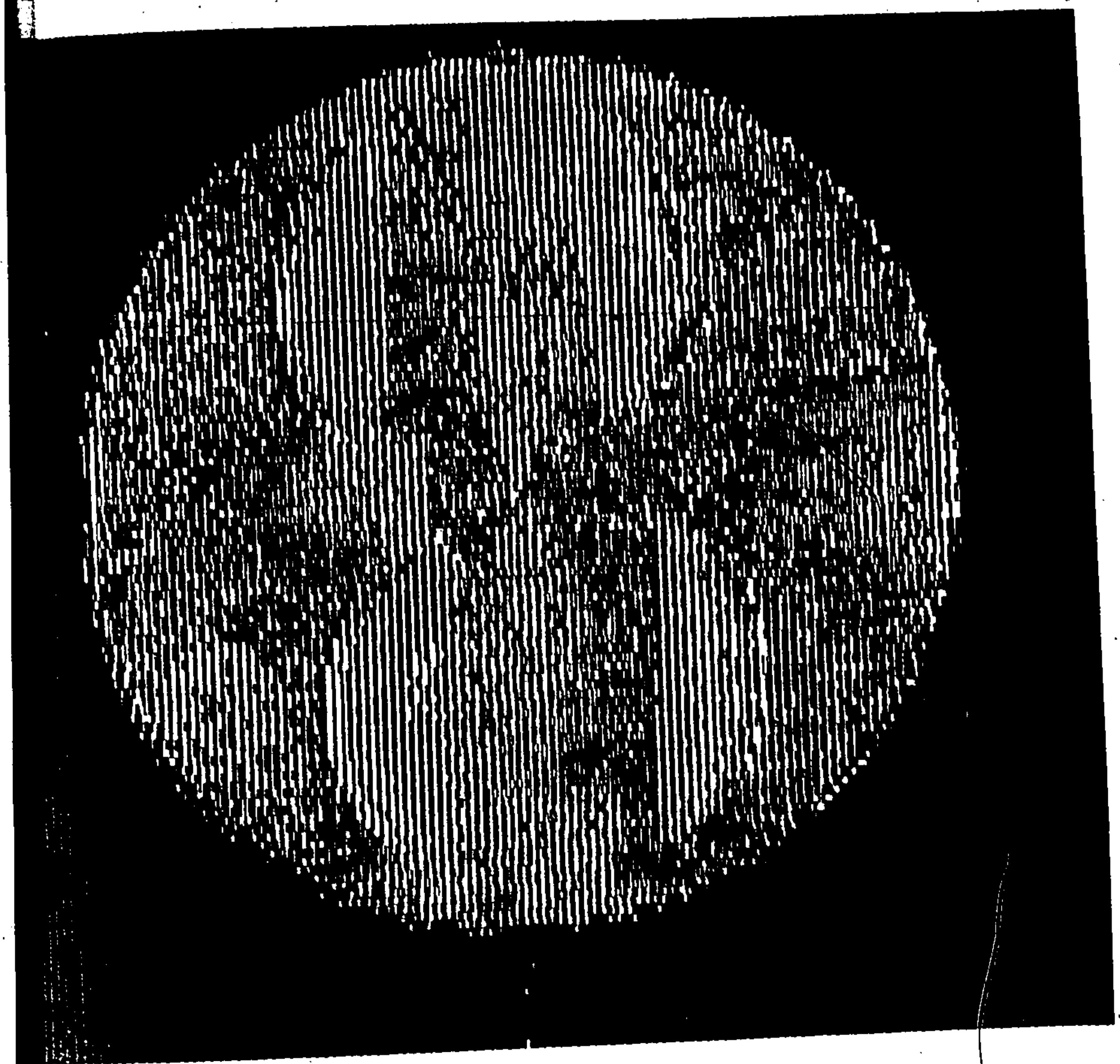


Fig. 4.8 Pseudo Colour by Triangular Transformation.

4.6.3 Trapezoidal Transformation

This transformation has produced the best results as compared to the previous two techniques.The triangular transformation failed to produce any magenta content among the lower gray level values, and any cyan colour among the higher intensities. In this technique the lower levels on the gray scale are composed of increasing yellow and decreasing cyan content [11].The middle range has a judicious proportion of the three primary colours and the higher levels have a decreasing yellow colour and an increasing magenta content.

A very homogeneous distribution of the colour dots within the matrix has further improved the visual perception.The lookup table generated by this technique had to be subjected to quite a few trials and modifications to produce a "good" image .As this technique does not lend itself to programming easily,the lookup table was generated by hand computations.Figure (4.10) illustrates a matrix for a pixel value of 21.

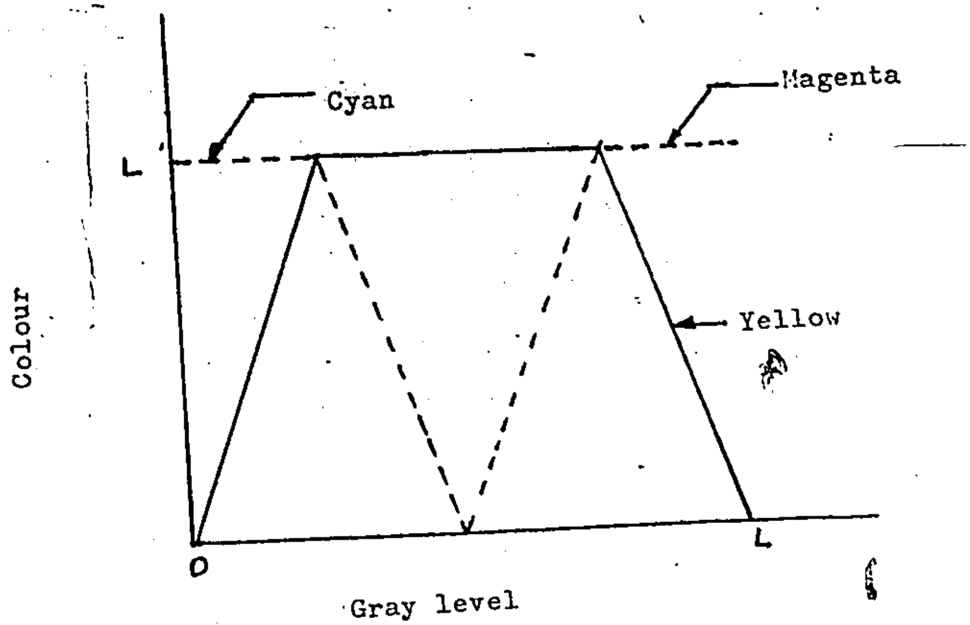


Fig. 4.9 Representation of Trapezoidal Transformation.

C	Y	C	Y	M	C
Y		M	C		Y
M	Y		C	M	
C	C		M	Y	C
Y		Y		C	Y
C	Y	C		Y	C

Fig. 4.10 Colour pixel representation for a gray level value of 21 by Trapezoidal Transformation.

Y - Yellow
C - Cyan
M - Magenta

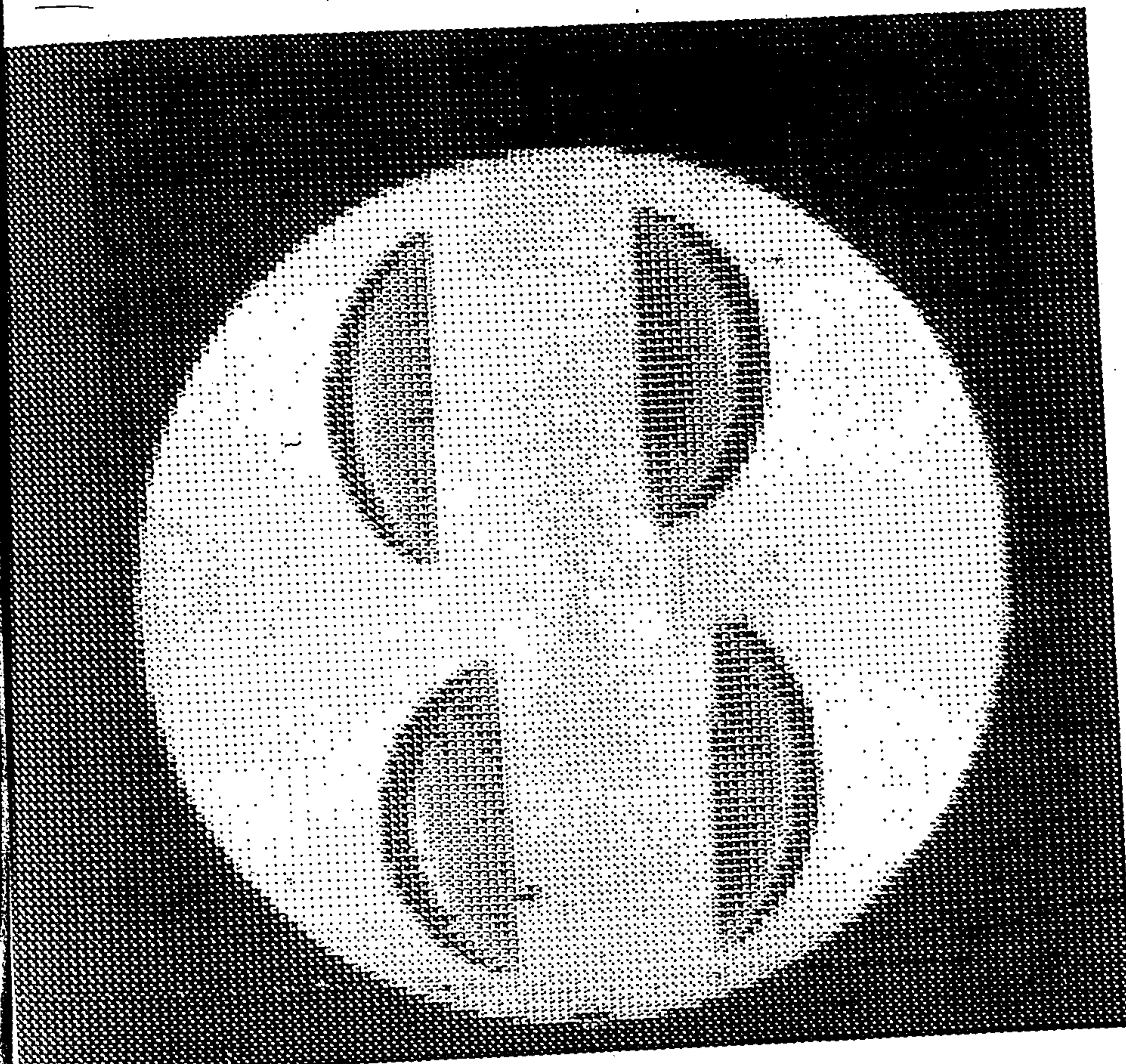


Fig. 4.11 Pseudo Colour by Trapezoidal Transformation.

4.7 INTERFACE TO THE EXECUTIVE

The printer can be activated by a touch switch in the executive to print a multicolour image.The software developed accepts the name of the image file,and initiates the printing after the data is fetched from the main memory.Images of the size 256 X 256 can also be produced in a similar manner.

An operator can print an image by initiating the Plot submenu, followed by the selection of 'PLOT' and the name of the image touch pads.A choice of the required lookup table can also be made before plotting the image.

Chapter V

SUMMARY AND CONCLUSIONS

The primary objective of this thesis is to inteface the Colorplot printer to the image processing executive and to provide software for obtaining a hardcopy of pseudo colour images. Lookup tables for generating pseudo colour have been designed and their effectiveness in relation to the visual perception is compared.

The best results in terms of fidelity was obtained by the trapezoidal transformation technique of mapping gray levels into three colour matrices for each of the primary colours. This technique is difficult to implement on the computer, hence all the values could only be obtained by means of simple hand computations. This is primarily due to the subjective nature of pseudo colour processing. A uniform distribution of the colour dots in a pixel can also be achieved by this technique.

The pseudo colour images are printed as a mixture of yellow, magenta and cyan dots in three passes, the form being reversed after each colour is plotted completely. The size of any image greater than 128 X 128 can only be plotted as multiple blocks of 128 X 128. Software for printing digitized images of different sizes has been developed.The Colorplot printer was interfaced to the SEL 32/27 through the I/O processor.

The plotting capabilities of the printer is supplemented by the software library provided by Cerritos Computer Services Inc..This package was modified to suit the current environment and the different modules in this library were tested.The Colorplot printer is highly versatile and can be used for plotting the data as an X-Y plotter.This feature has been extended to produce multiple plots with different colours on the same axis.A software driver routine to transfer plot data to the printer was also developed.

Appendix A

CALLING SEQUENCE FOR COMPONENTS OF TRILOG LIBRARY

A.1 SUBROUTINE PLOTS

CALLING SEQUENCE :

CALL PLOTS(R,L)

ARGUMENTS :

R Plotter Resolution

L Logical unit number for intermediate pen motions file.

For L=0 Unit='IPN'
L>0 Unit=L

A.2 SUBROUTINE FACTOR

CALLING SEQUENCE :

CALL FACTOR(Z)

ARGUMENTS :

Z Ratio of desired plot size to current plot size.

A.3 SUBROUTINE PLOT

CALLING SEQUENCE :

```
CALL PLOT(X,Y,I)
```

ARGUMENTS :

X X-coordinate of new position of 'pen'.

Y Y-coordinate of new position of 'pen'

I Pen control value.

```
=-9    Erase to (X,Y) and set new origin to (X,Y)
=-3    Move to (X,Y) and set new origin to (X,Y)
=-2    Draw to (X,Y) and set new origin to (X,Y)
=+2    Draw to (X,Y)
=+3    Move to (X,Y)
=+9    Erase to (X,Y)
=+10   Terminate current plot and eject page
=+11   Terminate all plots.
=+999  Terminate all plots
                   (included for compatability).
```

A.4 SUBROUTINE WHERE

CALLING SEQUENCE :

```
CALL WHERE(X,Y,Z)
```

ARGUMENTS :

X X-coordinate of current position of 'pen'

Y Y-coordinate of current position of 'pen'

Z Current overall scale factor

A.5 SUBROUTINE SYMBOL

CALLING SEQUENCE :

CALL SYMBOL(X,Y,H,T,A,N)

ARGUMENTS :

- X X-coordinate of symbol or text string
- Y Y-coordinate of symbol or text string
- H Height of symbol in plotter units
- T Text string or value of single symbol
- A Angle of text string or symbol from X-axis
- N Number of characters in text string
  - =-2 Draw line from current (X,Y) to new (X,Y) and then draw single symbol with value T.
  - =-1 Move from current (X,Y) to new (X,Y) and then draw single symbol with value T.
  - =0 No action.
  - >0 Draw symbols defined by text string contained in array T.

A.6 SUBROUTINE SCALE

CALLING SEQUENCE :

CALL SCALE(A,S,N,I)

ARGUMENTS :

- A Array containing data to be scaled.
- S Length of axis that will be used with the array.
- N Number of data values in array to be considered.
- I Increment between data values in array.

A.7 SUBROUTINE NUMBER

CALLING SEQUENCE :

CALL NUMBER(X,Y,H,V,A,N)

ARGUMENTS :

X X-coordinate of start of numeric character string.

Y Y-coordinate of start of numeric character string.

H Height of numeric character string.

V Value to be plotted as numeric character string.

A Angle of numeric string from physical X-axis.

N Format control value.

=-N V is truncated N-1 digits left of decimal point
=-1 V is truncated and plotted as an integer
=0 V is truncated and plotted with decimal point
=+N V is plotted with N digits right of decimal point.

A.8 SUBROUTINE NEWPEN

CALLING SEQUENCE :

CALL NEWPEN(I)

ARGUMENTS :

I Pen type value of the form 10*J+K.

J=0 no change in pen width
J=1-7 change pen width to J.

K=0 no change in pen colour.
K=1 change pen colour to Yellow.
K=2 change pen colour to Red.
K=3 change pen colour to Blue.
K=4-8 DONOT USE.
K=9 change pen colour to Black.

A.9 SUBROUTINE AXIS

CALLING SEQUENCE :

```
CALL AXIS(X,Y,T,N,S,A,F,D)
```

ARGUMENTS :

- X X-coordinate of the start of the axis.
- Y Y-coordinate of the start of the axis.
- T Title text string (Must be stored in a real array).
- N Number of characters in the text string.

  <0, Plot title on clockwise side of axis.
  =0, Plot no title.
  >0, Plot title on anti-clockwise side of axis.
- S Length of axis in plotter units.
- A Angle of axis from physical X-axis.
- F Scaling offset for first tic mark on axis.
- D Scaling increment between tic marks.

A.10 SUBROUTINE NEWMSK

CALLING SEQUENCE :

```
CALL NEWMSK(M)
```

ARGUMENTS :

- M Dot mask control word.

A.11 SUBROUTINE SHADE

CALLING SEQUENCE :

```
CALL SHADE(A,B,N,I,L,D,T,M,W)
```

ARGUMENTS :

A Array containing X-coordinates defining the area.

B Array containing Y-coordinates defining the area.

N Number of points defining the area.

I Increment between the points in arrays.

L Format control.

=-3 Outline and area erase.
=-2 Outline erase only.
=-1 Area erase only.
=+1 Outline only,no area shade.
=+2 Area shade only,no outline.
=+3 Outline and area shade.

D Distance between lines used to shade area.

T Angle of shading lines from physical X-axis.

M Dot mask control word.

W Working storage array length 3*N.

A.12 SUBROUTINE LINE

CALLING SEQUENCE :

CALL LINE(A,B,N,I,L,J)

ARGUMENTS :

A Name of array containing data for the abscissa.

B Name of array containing data for the ordinate.

N Number of pairs of points to be plotted.

I Increment control between points in arrays.

L Format control.

>0 Connect points by line with special symbol at point.
=0 Connect points by line with no special symbol.
<0 Plot symbol at point with no connecting line.

J Value of special symbol to be plotted.

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