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FFTF PROCESS DATA
DISPLAY PROTOTYPE

B. E. Dozer

April 1970

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FFTF PROCESS DATA DISPLAY PROTOTYPE

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FFTF PROCESS DATA DISPLAY PROTOTYPE

ABSTRACT

Interfacing of a four-color cathode ray tube display to a digital computer is described. Interface diagrams and a description of operation are provided. It is concluded that with appropriate display routines available such a display system is a valuable control room device.

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FFTF PROCESS DATA DISPLAY PROTOTYPE

INTRODUCTION

This report is written to describe development work performed on the application of a Philco-Ford, CRT color display system to the FFTF hybrid simulator. This work involves the design, fabrication and installation of the interface to connect the display to the digital computer. In addition, several methods of increasing the display system graphic capabilities were investigated and implemented. These included video projection, analog-to-raster scan conversion and alteration of the character generator for increased graphics capabilities. Three computer programs were written to apply the D-30 display to the PDP/9 computer. The first of these programs permits communication interchange between the computer and the display; the second provides improved graphic curve plotting capabilities; and the third consists of a record and list handling routine designed to improve the data handling efficiency of the computer-display system.

SUMMARY AND CONCLUSIONS

The D-30 display system is a raster scan, color TV, digital computer readout device. It is of basically good design, possessing its own internal memory for refreshing the output display periodically. A complete input-output data control system provides for a smooth flow of data between the display and the computer. Its high data transfer rate makes it ideal for virtually instantaneous display changes. It is equipped with a light pen which sends light pen address information on demand to the computer.

During the course of the development, the D-30 color display has shown itself to be an extremely valuable and versatile tool for data display. Its ability to produce four different colors coupled with its rapid display changing ability make it a dynamic output device. Its application in a control room environment will add another dimension to data presentation.

Work performed shows that the limited graphic capabilities of the D-30 display can be improved by using video projections of diagrams and backgrounds. Analog curves can be plotted with improved resolution over the incremental digital methods. Such curve plotting was accomplished by using a different digital character generator and by using a video scan converter.

Problems encountered during the course of the work indicate the reliability of the display should be improved for process control applications. This resulted from two factors. The unit was delivered in an inoperable condition; in fact, the development of some of the options included was not complete. It was also determined that the particular unit tested was one of the first of its type produced and, thus, not a trouble-free production model. Some trouble was also encountered with the transistorized color TV set. Additional testing indicated the intensity of the color TV set was insufficient for high level control room lighting. Addition of a brighter TV picture tube helped but did not completely eliminate the problem.

DISPLAY DESCRIPTION

Figure 1 shows the FFTF hybrid computer system. The PDP/9 digital computer is on the left, the analog computer on the right and the D-30 display system in the middle. The smaller CRT is a black and white unit that essentially duplicates the larger color display (CCTV compatible). Figure 2 shows a closer view of both displays. Figure 3 is a block diagram of the hybrid system including the proposed simulator control console. This device will be designed to closely approximate the console on the FFTF reactor. It will be used quite extensively for reactor operator training as well as to test proposed control instrumentation.

The Philco-Ford D-30 color display unit is a digital information display device for use with a digital computer. It receives digital data and control signals from an external device or from an alphanumeric keyboard and converts the data messages to video signals. These are displayed in four colors on a 525 line color television monitor. The D-30 is of the raster-scan TV type as opposed to the beam-steered data display.⁽¹⁾ It has the following general specifications:⁽²⁾

Display Type	- Raster scan
Video Output	- 525 line TV (digital video signal)
Refresh Rate	- Alternate interlace, - 60 fields/sec - 30 frames/sec
Video Bit Rate	- 11.34 megabits/sec
Display Size	- 16 in. wide, 12. high
Characters/Display	- 3456 characters/display
Display Format	- 48 rows of 72 characters/row
Character Format	- Dot matrix, 8 x 10
Character Size	
Alphanumeric	- 0.175 in. x 0.139 in.
Special	- 0.250 in. x 0.220 in.
Character Repertoire	- 26 Alphabetic - 10 Numeric - 23 Special

FIGURE 1. FFTF Hybrid Computer System

FIGURE 3. Computer System Block Diagram

Character Code	- Modified ASCII
Data Rate	-
Input and Output	- 315,000 8-bit bytes/sec 3456 characters in one memory cycle (one display field, 16.66 msec)
Electronic	-
Logic	- TTL and DTL plus MOS row memory
Clock	- Crystal oscillator, 11.34 MHz
Memory	- Magnetostrictive delay line - two units, each 8.33 msec. 42,000-bit total storage capacity.
Options	-
Light Pen	- Permits the address of the light pen location to be transmitted to an external device.
Selective Transmission	- Permits a selected portion of the dis- play screen to be transmitted to an external device.

The display unit accepts 8-bit parallel digital data from the external computer or the keyboard, stores these data and converts them into an alphanumeric and graphic representations viewable on the color television monitor. The incoming data are in the form of 8-bit bytes coded in accordance with a modified ASCII format which selects characters or symbols from a predetermined hardwired repertoire. These data bytes, as a function of the incoming message format, construct a display within the confines of a visible raster format of 48 rows with 72 characters or symbols in each row. Up to 3456 data bytes are stored in the display unit and are applied synchronously to display generation circuits which refresh the color monitor display at a rate of 30 frames per second. The color monitor accepts red, white, green and blue 525-line video signals and displays the characters and symbols in any of the four colors.

The input/output control circuits shown in drawing SK-3-15481 provide the data and control transfer capability between the display unit and the external device. A single set of eight data bus lines are used in the

half-duplex mode of operation. Control lines are provided for a demand response type of transfer. Mode selection and display format control are determined by means of unique 8-bit codes within the input or output data messages. The rate of data transfer is determined by the message memory delay line and is synchronous.

The data control circuits provide the addressing and storage of incoming data bytes from both the input/output interface and the keyboard interface. The entire display message is stored within the message memory in 3456 addressable character locations in the 48 row by 72 character matrix. The message memory consists of two 8.33 nsec magnetostrictive delay lines, connected serially; providing a total delay of 16.66 msec, or a data recirculation rate of 60 per sec. The stored display message is read from the message memory during recirculation and transferred to the display generation circuits. The memory control circuits include address counters for message memory addressing. Two sets of address counters are provided. Each set of counters defines a delay interval in the message memory loop equivalent to 8-bit times, or one character, in terms of its respective row and column location in the display matrix. One set of counters is continually running in synchronism with the message memory such that the counter output always defines the current character position available at the delay line interface. The remaining set of counters defines the next character position or address to be loaded and is controlled by the incoming message format to the input/output interface by control keys on the alphanumeric keyboard. Comparison of the outputs from the two sets of counters will provide a pulse equal to eight memory bit periods once per recirculation of data, or 60 times per second. This pulse is used to indicate memory access and to generate the display cursor.

The display generation circuits convert each 8-bit modified ASCII character code stored in the message memory into an 8 x 10 dot matrix within which the font or symbol is constructed. The one-zero pattern within the dot matrix may be in any conceivable configuration, but once defined, it is permanently hardwired for any given character generator circuit card. The display generation circuits shown on drawing SK-3-15481 consist of: row memory, character decode, character generator and video

generator components. The row memory is a dynamic serial memory utilizing MOS shift registers as the storage device. The row memory storage capacity is one character row of data or 576-bits (72 eight-bit characters). The serial shifting of the row memory data is in synchronism with the scanning of the television raster so that all 72 character codes complete one circulation during each raster scan line. The data continue to recirculate until all character dot matrices are generated for the respective display row. The output of the row memory is eight parallel bits corresponding to each consecutive character and is supplied to the character decoder. The character decoder accepts the 8-bit character code and provides a unique output for each character or symbol in the character generator repertoire. The character selection and timing signals are synchronized with the television raster and define the current scan line within a row. The output of the character generator is 8-bits in parallel for each sequential character in the line currently being scanned. These 8-bits correspond to one horizontal 8-dot row in a character dot matrix. The 8-bit parallel character generator output is accepted by the video generation circuit where it is serialized at the output video rate, gated by the color selection signals, and routed to the proper video distribution amplifier.

The sync and timing circuits are driven by a precision crystal oscillator which supplies the display unit basic video frequency. The sync and timing circuits consist of counters and decoding networks which generate all required clock, memory access, raster timing and monitor synchronization signals from the oscillator output.

PDP/9 COMPUTER - D-30 DISPLAY INTERFACE

The D-30 PDP/9 interface is used to interconnect the D-30 display and the PDP/9 computer. It permits information transfer in both directions between the two devices. There are three modes of information exchange: D-30 transmit, D-30 receive and light pen. In these modes the D-30 can be made to transmit to the computer on command of either the display or the PDP/9, while the D-30 will receive from the computer on command either by data channel or by single PDP/9 instruction. The light pen sends the address of the character being viewed by the pen when actuated by the operator.

Drawing SK-3-15482 and Figure 4 show a block diagram of the interface system. It consists of two 18-bit registers and gating logic to convert two 18-bit computer words from the PDP/9 to four 8-bit display words into the D-30. In transmitting from the computer, an 18-bit word is strobed into register A by actuating RSA with an IOT instruction. The same thing then occurs with the next computer word in register B. As soon as one register is full and the display timing correct, the first 8-bit word is taken out of the first half of register A and strobed into the display electronics by IWRD. A word counter then counts to four as it gates the proper section of either register into the D-30.

When transmitting from the display to the computer⁽⁴⁾, the word counter again selects the section of the registers where the 8-bit display words are stored. This is done through STO-8 A&B and STP-17 A&B. After register A is loaded with two 8-bit D-30 words, WRDA gates the register contents into the accumulator. The same process is then repeated as the contents of register B is gated into the accumulator with WRDB.

The light pen follows the same scheme as the above transmit mode but in this case different information is transferred to the computer.

Figures 5 and 6 show a flow chart of the transfer of data from the D-30 to the computer and from the computer to the D-30.

DISPLAY RECEIVE MODE

To receive information by single instruction from the PDP/9 computer an IOT-1 and 4 with a device selector code 50 must be sent by the computer (705005). The IOT-1 will actuate the channel select flip flop and hence

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FIGURE Simplified Interface Block Diagram

FIGURE 5. Flow Chart, Data Transfer D-30 to PDP/9

FIGURE 6. Flow Chart, Data Transfer PDP/9 to D-30

the D-30 Channel Select, while the IOT-4 will actuate the register strobe generator, both shown on SK-3-15484, Sheet 2. This generator produces Register Strobe-A (RSA) at the first IOT-4 and RSB at the second IOT. This has the effect of strobing the first 18-bit computer word into register A and the second in register B, shown on Sheet 4.

As soon as the information is in the registers, Data in Device Register A (DDRA) is actuated as well as DDRB for register B. DDRA in conjunction with the D-30 signal, Display Ready to Receive (RTR_D), generate Computer Ready to Transmit (RTT_C). RTR_D appears as soon as the channel select flip flop is actuated. RTT_C in conjunction with the word counter output $D0$ actuates One Word (1WRD) which applies the first 9-bits of register A to the 8, D-30 data bus lines. The first bit of the 9-bit word is not used by the D-30.

When the display senses the presence of RTT_C it accepts the data placed on the busses and removes RTR_D which deactivates RTT_C . This causes the word counter to advance to $D1$ and the process is repeated for the second 9-bit word in register A. When the second 18-bit computer word is in register B, DDRB is actuated and the system continues on to the third 9-bit display word. As the word counter is advanced to $D2$, the $D1$ signal resets DDRA which in turn resets register A. This permits the computer to again load register A. If a number of words are to be loaded into the D-30 in sequence, it will be necessary to test for an empty register before the loading command is given. This is done by issuing an IOP-1 on device selector 52 along with an SD-0 and SD-1. Known as a 705261 command, this performs a skip test and skips the next instruction if register A or register B is not full.

It should be noted that it is impossible to synchronize the D-30 display with the PDP/9 computer. This is because the D-30 operates at a standard television scanning frequency while the PDP/9 has a one micro-second clock time. In addition to this, the data must wait in the interface registers until the correct data storage entrance point is available at the display delay line memory.

When the computer has completed transmitting data to the display, the entire interface can be reset by issuing a 705204 command or an I/O Power

S1=LL	S2=LR	S3=05-3 & 05-4	S4=05-4 & 05-2	S5=05-3 & 05-2	S6=05-3 & 05-1	S7=05-3 & 05-1	S8=05-1 & 05-4

S10=05-1 & 2 & 7	S11=LL & LR	S13=05-1 & 2 & 3 & 4	S14=05-1 & 05-2	S15=UR	S16=05-3 & 4 & 5 & 8	S18=ALL	S19=LL & UR

S20=UL & UR	S21=UL & LL	S22=UL & LR	S23=UL	05-1	05-2	05-3	05-4
<p>IGB</p> <p>SL-0</p> <table border="1"> <tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td></tr> <tr><td>0</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>4</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>5</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>6</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> <tr><td>7</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr> </table> <p>MATRIX</p>						0	1	2	3	4	5	6	7	0								1								2								3								4								5								6								7							
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CHECKED		APPD.		B. E. Dozer		7/4/69				7/4/69	
DRAWN		B. E. Dozer		7/4/69		7/4/69				7/4/69	
BLDG NO.		55A		INDEX NO.		4801					
SCALE		NONE		CLASSIFIED BY		NONE					
DATE		2-9-70									
<p>DWG NO. SK-3-15483</p> <p>SHEET NO. 1</p> <p>SHEETS 4</p>

OON — SN7400N
 3ON — SN7430N
 16 — TTL 9016

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REV. NO.		REV. BY		DATE		DRAWING STATUS		APPD. BY		DATE		FOR		MICRO F.M'D		DATE	
DFTG		APPD		DATE		APPD		DATE		DATE		DATE		DATE		DATE	
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DRAWN		BPD		11/16/69		ENGR		B.E. DOZER		11/18/69		DATE		DATE		DATE	
BLDG NO.		55A		INDEX NO.		4801		DATE		DATE		DATE		DATE		DATE	
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DWS NO.		REV NO.		DRAWING TITLE OR INDEX NO.		REFERENCE DRAWINGS		U.S. ATOMIC ENERGY COMMISSION		RICHLAND OPERATIONS OFFICE		PACIFIC NORTHWEST LABORATORY		OPERATED BY BATTELLE MEMORIAL INSTITUTE		SPECIAL CHAR. GENERATOR-BR	
D-30 DISPLAY SYSTEM		SHEET NO.		2		SHEETS		4		DWS NO.		SK-3-15483		SHEET NO.		2

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PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE					
SPECIAL CHAR. GENERATOR - BR					
D-30 DISPLAY SYSTEM					
DWG. NO. SK-3-15483		SHEET NO. 3		SHEETS 4	

REV. NO.	REV. BY	DATE	DRAWING STATUS	APPD. BY	DATE	FOR	MICRO F.M'D
DFTG APPD			DATE	APPD			DATE
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DRAWN			1/18/67	ENGR			1/18/67
BLDG NO. 55A				INDEX NO. 4801			
SCALE NONE			CLASSIFIED BY 8902-100	CLASSIFICATION NONE			
			DATE 2-9-70

30N - SN7430N
40N - SN7440N
16 - TTL 9016

J-11

REV. NO.		REV. BY		DATE		DRAWING STATUS		APPD. BY		FOR		MICRO		F.M.D.	
DPTG APPD		DATE		APPD		DATE		APPD		DATE		APPD		DATE	
CHECKED		DATE		APPD		DATE		APPD		DATE		APPD		DATE	
DRAWN		DATE		ENGR		DATE		APPD		DATE		APPD		DATE	
BLDG NO. 55A		INDEX NO. 4801		CLASSIFIED BY		DATE 2-9-70		CLASSIFICATION		NONE		DWG NO. SK-3-15483		SHEET NO. 4	
SCALE NONE		CLASSIFIED BY		DATE 2-9-70		CLASSIFICATION		NONE		DWG NO. SK-3-15483		SHEET NO. 4		SHEETS 4	

Clear. A Power Clear may be sent by issuing a CAF (clear all flags) in the PDP/9 software or actuating the I/O Reset Switch on the computer control panel.

Should a higher speed data transfer to the D-30 be desired, the data channel mode may be used. This method makes use of a cycle stealing system on the PDP/9. It permits the transfer of large blocks of information at rates up to 250,000 words/sec with only one instruction. It operates through the W104 module shown in the upper left corner of drawing SK-3-15484, Sheet 2. The data channel mode is enabled by actuating the DCH flip flop with an IOT-1 instruction, a Device Selector 50 and Subdevice 0 (705041). This raises a flag which sets the Request Flip Flop (REQ) in the module. A data channel break is issued to the computer and, when ready, the computer answers with a Data Channel Grant (DCH GR) and a Data Channel Enable (DCH EN). The computer then starts to send out the previously arranged block of data until both Registers A and B are full. The device flag going to the REQ flip flop is then inhibited by DCH INHIBIT and the data stops until Register A is again empty. The REQ flip flop is reset by the DCH GR when the data channel is enabled and is reinstated by the device flag at the start of each word. The DCH INHIBIT is shown on drawing SK-3-15484, Sheet 4, and is produced by DDRA and DDRB or a signal that appears for 4 msec after DDRA is deactuated. The transfer of data from the registers to the D-30 is the same as with the single instruction mode.

DISPLAY TRANSMIT MODE

Information on the D-30 screen may be transmitted to the computer either by instruction from the PDP/9 software or by command. This is done through an automatic priority interrupt (API) actuated by a display keyboard button. The keyboard button actuates the D-30 INTERRUPT, shown on drawing SK-3-15484, Sheet 3, which in turn sets the INTER. flip flop and the API. To place the display in the transmit mode, a special RECALL message must be sent from the PDP/9 to the D-30. This message consists of three words: Start of Message (041), Recall (134) and End of Message (043). Once this is sent the display will wait for a Computer Ready to Receive (RTR_C) before transmitting data. The RTC_C is sent by the

computer issuing a 705122 instruction which actuates the RTC_C logic is shown on Sheet 3. When this is sent to the display, it responds with a Display Ready to Transmit (RTT_D). The RTT_D generates a STROBE pulse and, with DO , generates an ST-0-8A. The ST-0-8A stobes the data on the display data lines into the first half of Register A. In addition to this, the STROBE generates a DELAYED STROBE which advances the word counter and resets RTR_C . When the display detects the removal of RTR_C , it removes RTT_D which in turn reactivates RTR_C through the RTR_C flip flop. The whole thing repeats four times producing ST-9-17A, ST-08B and ST-9-176. Each of these strobe new display words into Registers A and B at the proper time.

When the fourth strobe pulse (ST-9-176) is produced, it sets the Register B Ready flip flop ($RBR-FF$). This sets the Data flip flop and again the automatic priority interrupt is actuated. This time the computer produces an IOT 705152 instruction which clears the accumulator and produces a WRDA output from the WRDA&B Generator. WRDA stobes the Register A contents into the accumulator during the second IOT-2. At this point a signal called Register A & B Reset is produced. It resets both the A and B registers.

Since the computer cannot easily determine when the computer message has been sent, it is necessary to test for the End-of-Message (EOM) signal. This is done by the STROBE pulse when the display word is on the D-30 data output lines. If the EOM is present, the EOM TEST circuit sets the EOM flip flop. The computer software then completes the procedure with a "flag search" and a "skip" routine to end the message.

To prevent extraneous signals from setting the transmit and light pen priority interrupts, a special enabling system has been used. This is shown in the lower middle section of drawing SK-3-15485, Sheet 4. To enable the system, the computer software must issue a IOT-4 on Device Selector 51 and an SD-0 (705144). This will set the D-30 ENABLE flip flop and permit actuation of priority interrupt modules.

LIGHT PEN OPERATION

Light pen operation is similar to the D-30 transmit mode. The difference is in the contents of the message transmitted to the PDP/9

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APPD.			OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
APPD. <i>A.P. Logan</i>		7/9/60	FFTF SIMULATOR	
ENGR. <i>M.E. Dues</i>		7/10/60		
DFTS APPD.				
CHECKED				
DRAWN <i>B.E.D.</i>		7/6/61	D30 DISPLAY INTERFACE	
SCALE <i>NONE</i>			LOGIC DIAGRAM	
CLASSIFIED BY		DATE	BLDG. NO. <i>55A, 300-GFF1</i> INDEX NO. <i>4801</i>	
CLASSIFICATION			DWG. NO. <i>SK-3-15484</i> SHEET NO. <i>4</i> SHEETS <i>4</i>	
NONE				

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DWG. NO.	REV. NO.	DRAWING TITLE OR INDEX NO.	DATE	CHECK PRT ISSUE NO.	DATE	LAST REV.

BY-DATE	FOR	BY-DATE	FOR	REV	BY	DATE	DESCRIPTION	REV

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computer. The light pen transmission consists of two different messages: one sent when the pen is actuated and another sent when the light pen ENABLE button is turned off. The first message consists of the following:

Start of Message - 041
 Input Status - 200
 Y Address
 X Address
 End of Message - 043

The second word, sent when the light pen is deactivated, consists of the following:

Start of Message - 041
 Input Status - 040
 Zero
 Zero
 End of Message - 043

The light pen is enabled through the interface by actuating the L.P. INTERRUPT shown on drawing SK-3-15484, Sheet 4. This interrupt then actuates the light pen API (automatic priority interrupt) which, when enabled, causes the computer program to jump to location 0066. The software then sends the RECALL message to put the display into the transmit mode and proceeds as if transmitting a message from the display screen.

VIDEO BACKGROUND GENERATOR

The Philco-Ford D-30 color display unit is a color TV, raster scan device. It generates its characters by lighting up dots in a 5 by 7 or 8 by 10 square matrix. Each 8 x 10 dot area is 0.250 in. high by 0.220 in. wide resulting in a total of 3456 areas or characters on the face of the cathode ray tube. The characters are generated digitally in the electronics of the device with the character selection resulting from an 8-bit code. Two of these bits are used to select the color leaving 6-bits for character selection or a total of 64 possible characters. Of these, 41 are used for alphanumerics and control resulting in only 23 special characters for graphic capabilities.

These 23 symbols can consist of any combination of the 8 by 10 dots but once selected, they cannot be changed without altering the display system circuitry. In the Philco-Ford system a group of horizontal, vertical and diagonal lines, as well as left and right hand corners, arrows, and line intersections, were selected for these symbols. Unfortunately, this limits the graphic capabilities of the system since any diagrams must be constructed using only these 23 symbols. Such problems are not present in the "beam steered" type display since the beam may be deflected to any portion of the screen at any time.

An example of the type of diagram generated by the display is shown in Figure 7. This shows a flow diagram of a fictitious primary and secondary heat exchanger. A number of measured variables have been added using the digital output of the character generator on the D-30 system. Some of the graphical problems are easily seen; in particular, the lack of curved lines. In addition to this, because of the symbols used, certain diagonal lines do not meet with the horizontal and vertical lines. Other more subtle problems include the lack of sufficient detail.

Advantages of this type of graphic presentation, not obvious from Figure 7, are:

- Exact correspondence between the diagram and the alphanumerics; no parallax or offset problems.
- No external equipment needed; all information is stored in the D-30 system memory.

FIGURE 7. *D-30 Generated Display*

FIGURE 8. *Etched Plastic Display*

- Equal brightness between the diagram and the data.
- All three colors usable for the figures.

Figure 8 shows the results of an alternate method of producing a similar diagram. This method, shown in Figure 9, utilizes an etched plastic transparent mask placed in front of the display cathode ray tube. The mask is edge lit with small lamps to illuminate the etched diagram while the figures show through from the display behind. Although not obvious from the photograph, much more detail including curved lines could have been included in the diagram. Obviously, the diagram complexity is almost unlimited since it is not determined by the symbols available on the D-30 system.

Problems in this system include the following:

- Parallax error between the data and the diagram.
- Multiple reflections.

External equipment needed.

- Etched plastic mask difficult to fabricate.

Figures 10 and 11 show the results of a video projection method. This system, shown in Figure 12, utilizes a television camera viewing a slide of the desired diagram. The camera changes the slide into a television signal which is viewed on the color display using the red gun on the cathode ray tube. By shifting the phase of the amplified camera output, either a negative or positive diagram can be produced. It can be seen that a more pleasing diagram results. Items such as valve symbols, liquid level floats, temperature bulbs, etc., are seen in Figures 10 and 11. In addition to this the original diagram is very easy to produce--a simple drawing with a photographed transparency is all that is necessary. Disadvantages of this system are:

- Depending on the sync signal, exact correspondence between the diagram and the data is sometimes difficult to attain.

Equal brightness and contrast between diagram and data is difficult to attain.

Complicated external equipment required.

- Only two colors are available for the data as one color is used just for the diagram.

FIGURE 9. Etched Plastic System

FIGURE 10. *Positive Video Projection*

FIGURE 11. *Negative Video Projection*

FIGURE 12. Video Project System

SCAN CONVERTER

Although the D-30 display system easily produces alphanumeric characters, problems are encountered if an attempt is made to display an analog graph. Plotting this type of graph can be implemented by using a device marketed by the Tektronix Corporation. This device, called a scan converter, changes conventional X-Y analog signals into a raster scan TV video output. It does this by displaying the X-Y signals on the screen of a special cathode ray tube in the conventional manner. This special tube has a memory type screen which is raster-scanned by a reading gun in the tube. This scan is done in sync with TV signals to produce the TV compatible reproduction of the memory screen. Since the screen is of the memory type, no refresh information is necessary after the X-Y signal is once produced.

The proposed system is shown in the block diagram on Figure 13. The analog signals from external sources connect directly to the X-Y inputs of the scan converter. Composite video and blanking are furnished by the D-30 display system while the video output of the converter drives one gun of the D-30 color monitor.

FIGURE 13. Scan Converter Block Diagram

DISPLAY SAMPLES

Figures 14, 15 and 16 show examples of some of the possible readouts on the D-30 display. Figure 14 consists of numerical listings of typical FFTF variables while Figures 15 and 16 show some of the more pictorial possibilities. The D-30 system is capable of changing any portion of any display in milliseconds so that continuous updating of any variable is easily accomplished. In Figure 14A, B or D, for example, a particular display could be called up from the computer. Any of the various flows, temperatures, pressures, etc., would then be updated automatically whenever a change occurred. Figure 14C shows a startup check list. In this case the items could be automatically checked off when the particular task is performed.

Figure 15A shows curve plotting efforts with the Tektronix scan converter. Figure 15C shows a comparison of the special character generator with the D-30 character matrix. These were described earlier in the report. Figure 15B, D and all of Figure 16 show a number of pictorial examples of what can be done with the D-30 character set. The black and white reproductions shown lose a dimension since they are not in color as produced by the D-30.

FIGURE 1 Display Samples

FIGURE 15. Display Samples

SCREEN BRIGHTNESS

The D-30 display system was apparently designed for use in semi-darkened areas such as radar system display rooms. Initial testing indicated that the cathode ray tube brightness was insufficient for use in a modern, brightly-lighted control room. Further investigation showed that a darkened, polarized screen had been placed over the CRT face. This was done to alleviate some of the flicker present on the display. A new cathode ray tube was installed without the polarized screen or the special anti-reflective coating applied to most CRT's. Considerable improvement was noted in the display brightness, but it was not as bright as a conventional black and white TV display. Some comparison between the brightness of the black and white and the color displays can be seen in Figure 2. Operation of the unit in a normally lighted control room will probably require some type of hood. The removal of the polarized screen caused a noticeable flicker but after operation of the display for a short time, the operator becomes insensitive to it.

SPECIAL CHARACTER GENERATOR

It is sometimes advantageous to present the output of a digital computer as an analog graph. This can be done quite easily with a digital-to-analog converter and an analog recorder. Such a graph can also be constructed on digital output devices such as line printers, teletypes and digital displays. The graph is produced by plotting points in fixed increments corresponding to the line and character size of the type. The result will then be an irregular line of asterisks or "X's"; for example, to indicate the analog curve. Such a system may suffer somewhat from a lack of resolution because of the discrete intervals on the plotting device.

An increase in the resolution can be effected by producing a larger number of smaller plotting characters. Such a system was tried with the results shown in Figure 15C. Here the standard rectangular character matrix was divided into four smaller rectangular characters. All combinations of these rectangles were created with the character generator shown in drawing SK-3-15483, Sheet 1. Symbols S1, S2, S9, S11, S15, S19, S20, S21, S22 and S23 are those used for the curve plotting. The remaining symbols merely replace the symbols on the manufacturers standard character generator. The "S" numbers refer to the display keyboard key numbers.

The characters are produced by intensifying a pattern of dots in a matrix. This matrix, shown on the lower portion of drawing SK-3-15483, Sheet 1, is eight dots wide by 10 dots high. It is generated for each of the 72 characters in 48 lines in an alternate interlace fashion--field one intensifying lines SL-0, 2, 4, 6 and 8 and field two the remaining lines. The intensifying signals are generated digitally with the logic shown on drawings SK-3-15483, Sheets 2, 3 and 4. The alphanumeric character set is generated in another generator and is fed to the video system through the new generator. These alphanumerics enter board J11 on drawing SK-3-15482, Sheet 4, as the signals marked IGB-2, 3, 4, 5 and 6--they leave for the video system as IBG-2, 3, 4, 5 and 6. The signals IBG-0, 1 and 7 represent the spaces between the characters and therefore contain no alphanumeric information.

To explain the operation of the generator the production of one symbol will be followed through the logic. When Key S1 is actuated on the D-30 keyboard, a special code for this key enters the D-30 delay line memory. This code recirculates in the memory and at the proper time, corresponding with the location on the raster, **it** is removed and decoded where **it** actuates Signal $\overline{ST}$ on Pin 44 of J10. **It** is shown on the top center of SK-3-15483, Sheet 2, where **it** is designated as LL (lower left). Here, through an "or" circuit with some other signals, **it** actuates $\overline{LS-1}$ by "anding" with the bottom five lines of the matrix (SL-5, 6, 7, 8, 9). Thus, whenever LL (S1) is actuated together with any of these five horizontal lines, $\overline{LS-1}$ is energized. The signal $\overline{LS-1}$ is then connected to the IBG-0, 1, 2 and 3 signals on SK-3-15483, Sheet 4, through a series of "or" circuits. These in turn produce video outputs whenever the proper coordinates on the matrix are actuated.

SOFTWARE

Three different programs were written for use with the PDP/9 D-30 system: LPDM-3, CLRDSP and a record handling program. LPDM-3 contains three subroutines. They are PLOT, DRAW and LABEL. When the LPDM-3 program is called, a list of words appears in the lower right hand corner of the screen. These words (clear, draw, label and terminate) describe the task that will be performed when the D-30 light pen is actuated while pointing at the particular word. Subroutine DRAW produces a vector between two points on the D-30 screen when selected by light pen strikes. DRAW uses the PLOT subroutine to connect the two points. PLOT utilizes the special character generator described earlier to plot any graph of X and Y in addition to its use in the DRAW subroutine. For graph plotting the coordinates are set up first, then the program is called and the values of X and Y are plotted incrementally.

LABEL is a subroutine that allows characters to be moved around on the screen. The overall objective is to provide a simplified method of drawing diagrams. To use LABEL, the operator types the desired symbols on an unused portion of the screen. He then points the light pen at the desired character, actuates the pen and moves it to the proper diagram location. The second light pen strike deposits the symbol at the second location. The "clear" and "terminate" words on the screen initiate and halt the LPDM-3 program.

CLRDSP is a program used to transfer data between the D-30 and the PDP/9 and to test the operation of the light pen. The program is implemented by starting at Location 200. Then, with a display on the screen, the transmit button on the D-30 is actuated, and the display contents are transferred to the computer. The starting memory location of the display is selected by the accumulator switches on the front panel of the PDP/9. In this program, selecting 777, 5477 or 12477 (octal) will place the display contents in locations starting with 1000, 5500 and 12,500 (octal).

Once three different displays are loaded into memory, the display may be changed by using the light pen. This is done by switching the light pen on and selecting either the top, middle or bottom right section of the screen with a light pen strike. The top selects display 1000 the middle,

5500 and the bottom 12,500. Light pen strikes on the left section of the screen select the first few characters of the last display (12,500) and place them on the top, middle and bottom left section of the screen.

The program also contains subroutines to test the writing ability of the PDP/9. By starting the program at location 400, the computer will transmit the contents of display 1000 to the D-30. It does this one word at a time, requiring about 30 seconds to completely write the display. Starting at location 500 will write the same display by data channel requiring only milliseconds for one complete display.

Two standard PDP/9 programs permit transferring the complete CLRDSP program including the three displays on and off of DEC tape (PDP/9 magnetic tape). The write program called CORIT writes on the tape while the MASIER READER reads the tape and transfers it to core memory. With these two programs, any display from a large number stored on magnetic tape can be produced on the D-30 in less than a minute.

The record handling program⁽⁵⁾ has been studied in an attempt to increase the efficiency of the display data handling system. Since any one display contains more redundant data (blanks) than anything else, it would seem somewhat wasteful to store all these data. Efforts were made to list various meaningful sections of any display and call each one of these records up as needed. Such a program would be valuable in updating data as well as changing display patterns.

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3. Logic Handbook, C-105, Digital Equipment Corp., Battelle-Northwest, Richland, Washington (1968).
4. PDP-9, 9/L Interface Manual, DEC-09-H7AA-D, Digital Equipment Corp. , Battelle-Northwest, Richland, Washington (1969).
5. T. A. Seim. Unpublished Data (private communication) , Battelle-Northwest, Richland, Washington (1969).

APPENDIX A

COMMERCIAL COMPONENTS*

Purchased Equipment:

- Philco-Ford D-30 color display
 - Control electronics
 - Character generator
 - Selective transmission option
 - Light pen option
 - Black and white monitor
 - Keyboard
- Sylvania, "Colorbrite 85" color picture tube 22LP22
- Tektronix, R4501 scan converter
- Burke and James, "Orbitor" 4 x 5 camera with polaroid adapter
- Digital Equipment Corp. modules for display-computer interface
- Scientific Atlanta electronic mounting cabinet
- G.B.C. television camera.

* In custody of BNW Computer Systems Development Section, 7M32.
As of 3/70 was located in BNW Math Building.

APPENDIX B

INFORMAL TECHNICAL DOCUMENTATION*

1. B. E. Dozer. "Diagram Generation on the Philco-Ford D-30 Color Display," Computer Systems Development Memorandum 69-11, August 28, 1969.
2. B. R. Smith. "LPDM-3," Computer program, source Dectape (1969). (Tape in the possession of N. B. Smith, 3/70.)
3. B. E. Dozer. "CLRDSP VA" Computer program, source and object paper tape (1969). (Tape in the possession of B. E. Dozer, 3/70.)
4. R. E. Mahan. "Task IC-51 - Quarterly Documentation," December 19, 1968.
5. M. D. Erickson and B. E. Dozer. "FFTF-IC 51 - Quarterly Documentation," April 2, 1969.
6. M. D. Erickson and B. E. Dozer. "FFTF (WPA-104) - quarterly Documentation," August 14, 1969.
7. M. D. Erickson. "FFTF Process Data Display/Control Room Mockup," October 6, 1969.

* Unless otherwise noted, quarterly documentation is in possession of .
G. G. Thieme, 703 Building, Richland, Washington, as of 4/70.

APPENDIX CGLOSSARY OF ABBREVIATIONS^{*}

API	Automatic priority interrupt
ASCII	American standard code for information interchange
CAF	Clear all flags
CCTV	Closed circuit television
CLRDSP	Color display program
CRT	Cathode ray tube
DDRA	Data in device register-A
DDRB	Data in device register-B
DCH	Data channel
DCH EN	Data channel enable
DCH GR	Data channel grant
DTL	Diode-transistor logic
EOM	End of message
FFTF	Fast Flux Test Facility
INTER	Interrupt
I/O	Input-output
IOT	Input-output transfer
LPDM	Light pen demonstration program
REQ	Request
RSA	Register strobe-A
RSB	Register strobe-B
RTR _C	Computer ready to receive
RTR _D	Display ready to receive
RTT _C	Computer ready to transmit
RTT _D	Display ready to transmit
TTL	Transistor-transistor logic
1 WRD	One word
WRDA	Word-A
WRDB	Word-B

* The remaining abbreviations not listed here are, in general, symbols used to tag the various signals within the logic wiring diagram. Their initials do not stand for any particular words.

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