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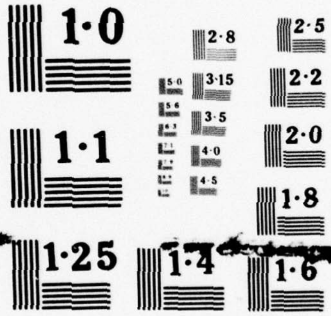

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DEVELOPMENT OF A PROGRAMMABLE PANEL

Display Systems Laboratory
Hughes Aircraft Company
Centinela & Teale Streets
Culver City, California 90230

NOVEMBER 1977

Final Report for Period 15 June 1975 to 15 July 1976

Approved for public release;
distribution unlimited

Prepared for

NAVAL AIR DEVELOPMENT CENTER
Warminster, Pennsylvania 18974

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

(19) REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. ~~REPORT NUMBER~~ (18) NADC 77264-30
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle) (6) Development of a Programmable Panel.

5. TYPE OF REPORT & PERIOD COVERED Final Report 6/15/75 – 7/15/76

6. ~~PERFORMING ORG. REPORT NUMBER~~ (14) HAC-P77-383, HAC-Ref-D4443

7. AUTHOR(s) (10) G. Wolfson

8. ~~CONTRACT OR GRANT NUMBER(s)~~ (15) N62269-75-R-0372 NEW

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Display Systems Laboratory ✓
Hughes Aircraft Company
Centinela & Teale Sts., Culver City, Ca. 90230

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS (9) Final rept. 15 Jun 75 - 15 Jul 76,

12. REPORT DATE (11) Aug[redacted]77

13. ~~NUMBER OF PAGES~~ 2

14. ~~MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)~~ (12) 30p.

15. SECURITY CLASS. (of this report) Unclassified

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Controls, Liquid Crystal Alphanumeric Display, Programmable Switch Panel

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A programmable control panel utilizing a liquid crystal alphanumeric display with four lines of twenty characters each was designed and fabricated. The panel features ten pushbuttons with the liquid crystal display providing two lines of four characters each as a programmable pushbutton legend. This panel was designed to demonstrate liquid crystal alphanumeric display technology as applied to advanced integrated controls and displays for future Navy avionics systems.

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PREFACE

This final report covers the work accomplished during the period 15 June 1975 through 15 July 1976 under Contract N62269-75-R-0372, Development of a Programmable Panel. This work was supported by the Naval Air Systems Command under the sponsorship of Mr. George Tsaparas and Mr. Russell Berthot. The program was under the technical direction of Mr. Ken Priest and Mr. Karl Quiring of the Naval Air Development Center, Warminster, Pennsylvania. The work was accomplished by the Display Systems and Human Factors Department under the direction of Mr. G. Wolfson who was Project Manager.

Special acknowledgment is given to Mr. W. Lewis who was responsible for the mechanical design and directed the unit fabrication effort.

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SECTION 1
INTRODUCTION AND SUMMARY

The Advanced Integrated Display System (AIDS) will provide for integrated controls and displays that optimize information transfer and weapon system control with a new degree of flexibility. An important feature of the AIDS system is the simplification of the operating controls for the manual selection of desired data and displays. A sensible way of providing this feature is through the use of a multi-format programmable switch panel containing the necessary control logic and switching. In addition to the requirement for programmability, the control panel must be viewable in a high ambient environment and occupy a minimum of cockpit real estate. Like most control panels, it is highly likely that the unit will be console mounted (as opposed to instrument panel mounted), thereby implying a severe restriction on the unit's depth.

Under the AIMIS program, the Navy has sponsored a number of technology developments that directly support the AIDS requirements. In particular, the Master Monitor Display (MMD) program (NADC Contract N62269-75-C-0296) established the feasibility of liquid crystal display technology for the display of alphanumeric data.

As a natural extension to the MMD liquid crystal display effort, a Programmable Control Panel utilizing the technology developed for the MMD was designed and fabricated. This liquid crystal programmable panel is the subject of this report.

A photograph of the programmable panel is shown in Figure 1. The control panel consists of four lines of alphanumeric liquid crystal displays and two rows of five push buttons. The alphanumeric liquid crystal displays are identical to those used with the MMD. Each display row contains 24 characters. However, for this application, only 20 of the characters are utilized. Each of the five push buttons in a row are lined up and associated with 4 alphanumerics in each of the two display rows above it.

In addition to the control panel itself, an electronics interface unit was designed and built to permit inputting of data from a Hickok 960A

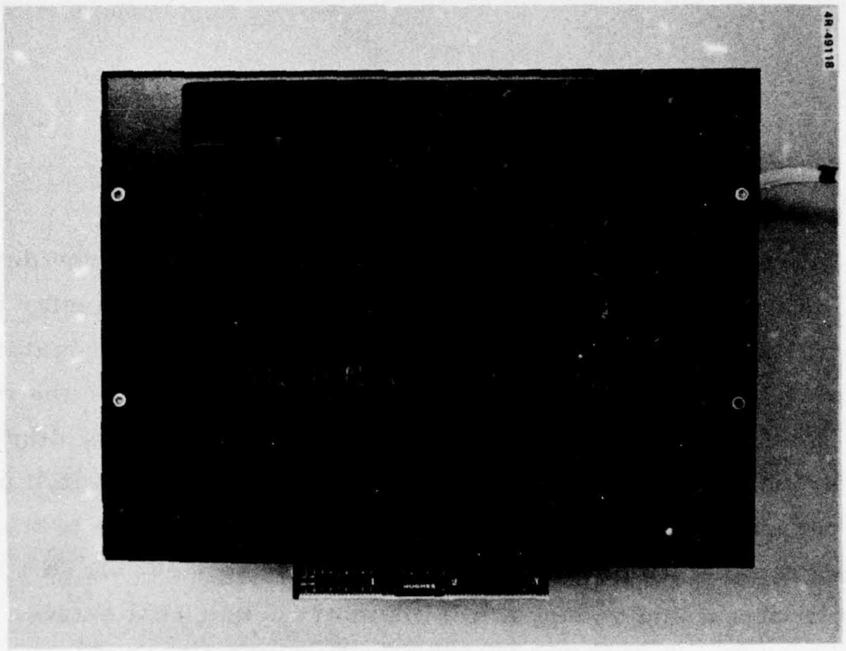


Figure 1. Programmable panel.

80 column static card reader. This interface unit is shown in Figure 2, along with the control panel.

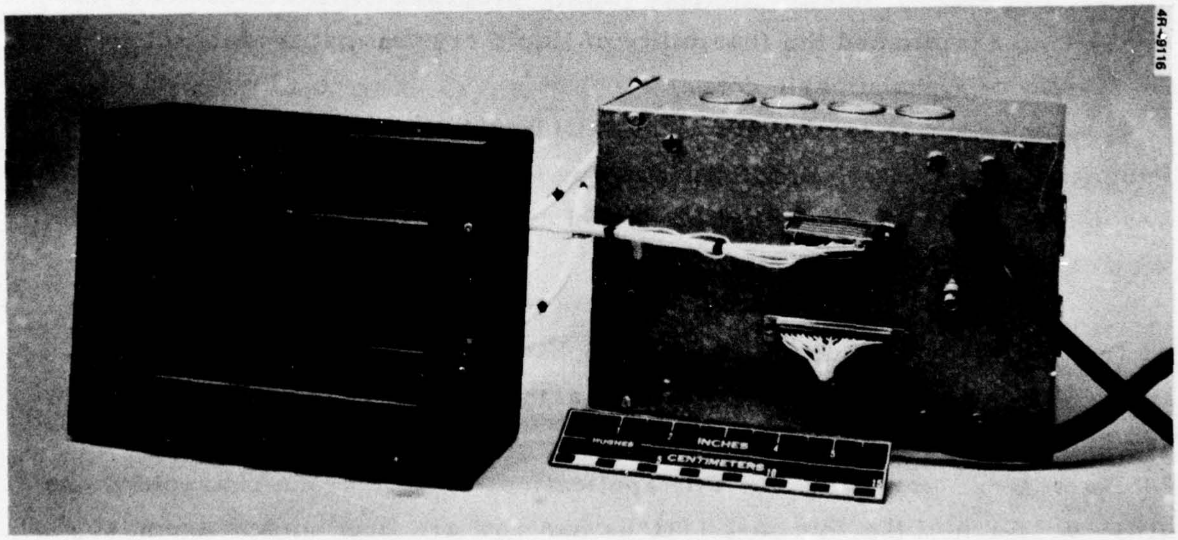


Figure 2. Programmable panel with interface unit.

SECTION 2

TECHNICAL DISCUSSION AND APPROACH

INTRODUCTION

The technical approach taken in the development of the Programmable Panel was to provide the pilot or operator with a control unit containing four lines of liquid crystal alphanumeric characters in a stand-alone unit which contains all required storage and drive electronics. To maintain simplicity and maximum reliability the number of interface connections to the source of input data was minimized.

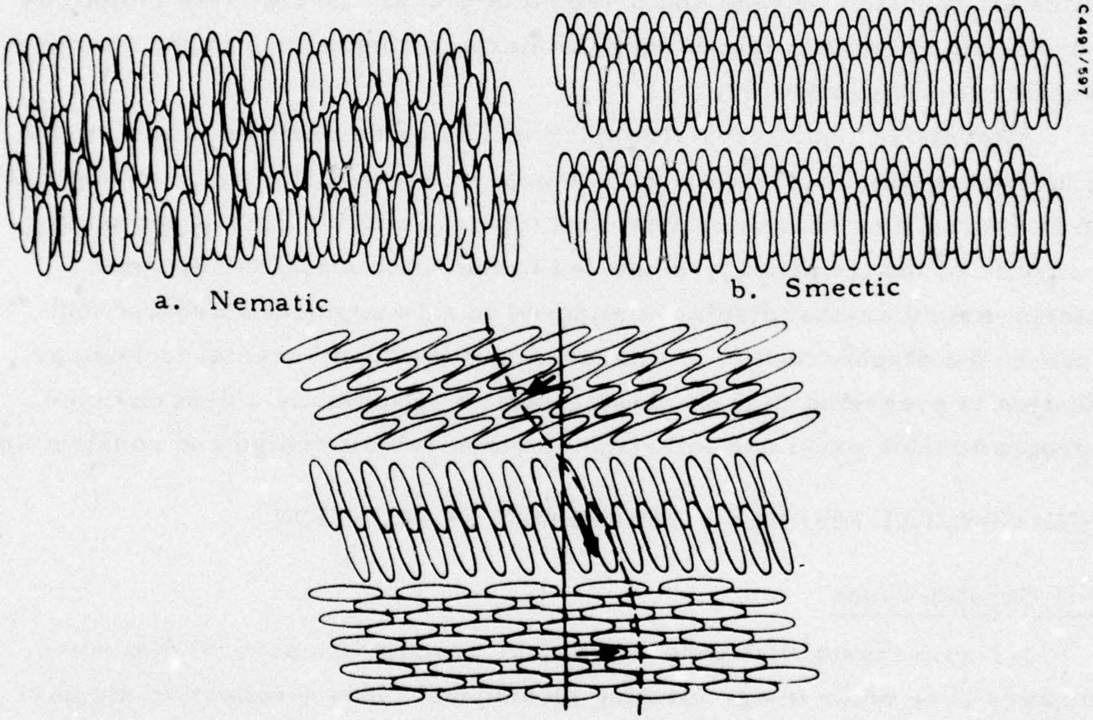
Alternative liquid crystal display technologies were reviewed for the programmable panel application with primary consideration given to legibility, off axis viewability, character font, and electronic drive circuit complexity. The results of the technology review led to the selection of the dynamic scattering liquid crystal display configured in a 14 segment starburst font for use as the display media. A discussion of the liquid crystal technology evaluation is presented in the following section followed by a description of the programmable panel and interface electronics unit design and construction.

LIQUID CRYSTAL DISPLAY TECHNOLOGY EVALUATION

Liquid Crystal Types

A liquid crystal flat panel display or readout has several distinct advantages over other image forming techniques. It is a reflective display and therefore it maintains contrast under high ambient illumination; if the ambient lighting doubles, the brightness doubles. It requires only milliwatts of power, because it is a light switch rather than a light source. Additional advantages of liquid crystal displays and readouts include greatly reduced size and weight due to the flat panel shape factor and increased reliability resulting from the solid state technology.

Liquid crystal types are classified according to their molecular structure as (1) Nematic, (2) Smetic, or Cholesteric. Nematic liquid crystals consist of molecules that are parallel, resembling matches in a box. Each molecule can rotate only around its long axis and has some freedom from side to side or up and down (Figure 3a). The smetic liquid crystals have a layered arrangement. The layers can slide over one another, because the molecules in each layer can move from side to side or forward and backward but not up and down. Within each layer, molecules may be ordered in ranks (Figure 3b) or randomly distributed. The cholesteric liquid crystal (LCD) consists of layers, as smectic LCDs do. Within each layer, however, the molecules are parallel, as are the nematic molecules. Molecules in one layer exert an influence on the layers above and below, so the long axis of the molecules in these layers is displaced slightly and a helical pattern forms from layer to layer (Figure 3c).



a. Nematic

b. Smectic

c. Cholesteric

Figure 3. Diagrams of packing effects in liquid crystals.

The nematic liquid crystal operating is either a Dynamic Scattering Mode or Field Effect Mode was considered for the current display application.

In the dynamic scattering mode (DSM), a thin layer of liquid crystal material is sandwiched between two electrodes as shown in Figure 4. The outer electrode is transparent and the back electrode is reflective. When

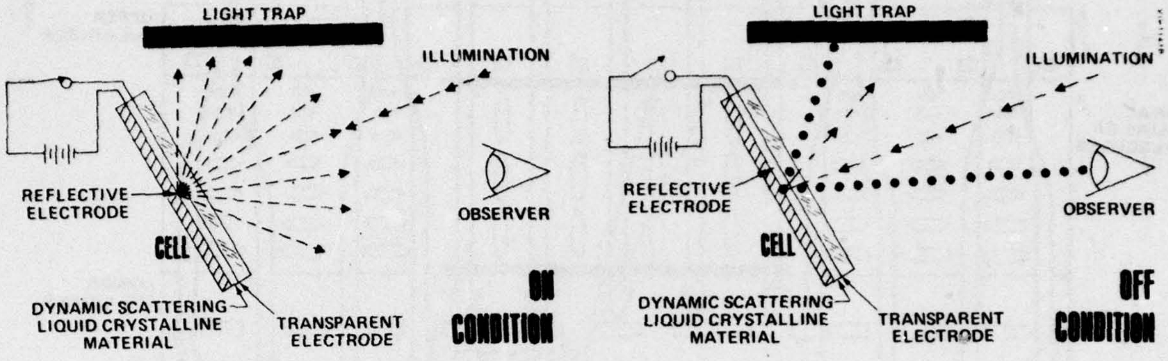


Figure 4. Dynamic scattering liquid crystal cell operation.

the electrodes are at the same potential, the liquid crystal material is clear and the observer will see a reflection of a dark light trap giving him the impression that the cell is black.

When the electrodes are at different potentials, the material develops scattering centers which forward scatters the incident light. The scattered light is reflected back to the observer giving him the impression that the cell is white. The amount of light reflected to the observer can be controlled by the electrode potential. DSM can be activated by either AC or DC signals. Typically, AC frequencies less than 1 kHz are used.

In the field effect mode, the liquid crystal material is sandwiched between two polarizers placed at right angles to one another (Figure 5). The layers of molecules in the fluid are arranged in a helical stack, like a spiral staircase. The light coming through the front polarizer is rotated 90 degrees as it travels down the "staircase," it passes through the rear polarizer and is reflected by the mirror. When a potential is applied between the electrodes, the liquid crystal molecules are rotated 90 degrees so they are perpendicular to the front polarizer. Light that passes through them is not rotated and therefore is absorbed by the rear polarizer. The result is a dark digit that contrasts with the light surroundings. The digits can be made light and the background dark by rotating the polarizer 90 degrees.

Both the dynamic scattering and field effect LCD can provide a highly legible high contrast display. The primary advantages of the field effect

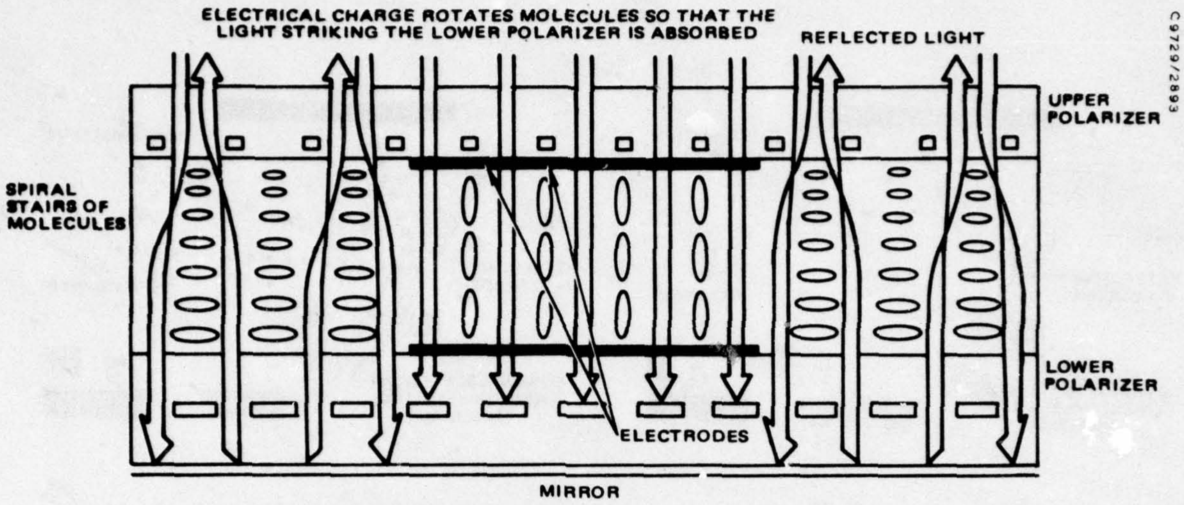


Figure 5. Field effect liquid crystal cell operation.

LCD over the dynamic scattering LCD is lower voltage requirements (1.5 volts versus 15 volts) and the lack of a light trap requirement. The disadvantages of the field effect LCD include, limited off axis viewing to approximately 20 degrees and the requirement for a transparent substrate. The need for the transparent substrate does not permit electrical contact with the display segments via pins brought out through the back of the substrate. Electrical connection to the elements must be made along the top and/or bottom of the display therefore requiring a substantial spacing between display rows.

The dynamic scattering mode LCD is recommended for use in the Programmable Panel due to its high contrast, excellent on and off axis viewing and the ability to use a non-transparent substrate which permits the use of rear pins for electrical contact.

Legibility Considerations for Liquid Crystal Programmable Panel

The legibility of the symbols is the main consideration in determining symbol formats. Legibility is affected by many factors, but those that impact most directly on design trade-offs for the present application are symbol subtense, contrast, font, ambient illumination, number of elements used to construct the symbol, and matrix type; e.g., an array of segmented elements or dot elements. Each of these factors and associated design tradeoffs will be discussed in the context of legibility for the Programmable Panel.

Matrix Type and Font

Several symbol legibility studies have been conducted to examine the legibility of segmented and matrix symbols; however, there are no known studies that have directly compared segmented alphanumerics against dot-matrix symbology, and therefore any conclusions as to the relative desirability of one form of presentation over the other must be qualified. The results of the most relevant studies will be discussed in the following paragraphs.

Most recently, Shurtleff[ref 1] reports that a fixed stroke matrix (16 segment starburst) yields 3 percent higher error rates and a 25 percent reduction in speed of identification in a symbol reading task when compared to a less constrained geometrical form of stroke-written symbology (random position stroke). Additional studies reported by Shurtleff[ref 1] show no legibility differences between random position stroke and 7 x 11 dot-matrix symbology. These studies taken at face value would lead one to conclude that 7 x 11 dot-matrix symbology is superior to 16 segment starburst symbology. However, during the Shurtleff studies, particular emphasis was placed on maintaining the same geometrical style of symbology across the various experimental conditions. This provides excellent experimental control but makes the relevance of the results to real world application questionable, because in reality one would optimize the style or font of alphanumerics to whatever symbol construction technique was selected. Indeed, style was allowed to vary in some of the following studies, and differences in construction technique (segmented, dot, or stroke) are far less conclusive. Stephenson and Schiffler[ref. 2] conducted a study to test the relative legibility of five segmented matrices consisting of 16, 17, 23, 27, and 38 elements. The relative accuracy of identifications for brief (0.25 sec) exposures indicated no trend toward better performance as the number of elements increased. The 16 and 23 element matrices were slightly superior when font was not artificially constrained by experimental controls. Stephenson and Schiffler conclude that even though 16 and 23 element segmented symbology

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[1] Shurtleff, D. A. Legibility Research. Paper Submitted for Publication, Society for Information Display, 1974.

[2] Stephenson, S. D. and Schiffler, R. J. The Relative Legibility of Five Different Segmented Electroluminescent Fonts. RADC-TR-68-372, Rome Air Development Center, Griffiss Air Force Base, New York, September 1968.

was superior that the principal advantage of the 16 segment matrix lay in the lower cost and complexity of the drive electronics.

It has been found that other perceptual variables as well as task related factors can interact with matrix type in the measurement of symbol legibility. A study by Plath (1970) compared standard AMEL numerals to segmented numerals having one-half the stroke width against the criterion of legibility. This confounding with stroke width was approximately equivalent to doubling the luminous intensity of the AMEL numerals as found by Vanderkolk, Herman, and Hershberger ref. [3]. Thus it is not surprising that the results indicated the superiority of the standard AMEL numerals.

Gibney ref. [4] reviewed the literature and found that increased task complexity affected the relative legibility of standard Arabic and segmented symbology in such a way as to reduce any differences in legibility. Gibney later confirmed this finding with his own laboratory experiments and concluded that segmented numerals can be used in many practical situations without compromising performance, especially considering the reduction in cost and electronic complexity.

One further study by King, et al ref. [5] in which subjects read three-digit numbers from segmented readouts reinforces the previous findings. The results indicated that pilots could read the numeric readouts with 100 percent accuracy even at minimum values of contrast; although, the latter conditions required longer reading time.

Finally, Meister, et al ref. [6] state that differences in legibility between segmented and 5 x 7 dot-matrix are small and that the advantages deriving from reduced electronic complexity are substantial.

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[3] Vanderkolk, R. J., Herman, J. A. and Hersberger, M. L., Dot Matrix Display Symbology Study. Hughes Aircraft Company. P75-114K, March 1975.

[4] Gibney, T. K. Legibility of Segmented Versus Standard Numerals: A Review. AMRL-TR-67-116, (AD 661 262), Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, June 1967.

[5] King, R. C., Wollentin, R. W., Semple, C. A., and Goettelmann, G. Electroluminescent Display Legibility Research and Development. AFFDL-TR-70-89, Air Force Flight Dynamics Laboratory, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, August 1970.

[6] Meister, D. and Sullivan, D. J. Guide to Human Engineering Design for Visual Displays. Office of Naval Research Contract Number N00014-68-C-0278 (AD 693-237), Engineering Psychology Branch, Office of Naval Research, Washington, D. C., August 1969.

It is concluded from the foregoing discussion of the legibility of segmented, continuous stroke, and dot-matrix symbology that any differences stemming from symbol construction technique, if indeed there are any, are far overshadowed by other considerations such as reduced electronic complexity.

Symbol Subtense

The effect of symbol subtense on the legibility of symbology has been well established. Symbol subtense is the angle subtended by the symbology at the eye of the observer. Streeter, Weber, and Opittek$^{\text{ref. }7}$ conducted a laboratory study and recommended that alphanumeric symbology for an aircraft Master Monitor Display subtend 30 minutes of arc noting however, that 22 minutes of arc would be acceptable if vertical spacing between lines was at least 30 minutes. VanderKolk, Herman, and Hershberger$^{\text{ref. }3}$ reviewed the literature and found that symbology should subtend between 22 and 26 minutes of arc to ensure good legibility under normal operating conditions. Under ideal viewing conditions, e.g., high contrast, no vibration, and no symbol motion, symbol subtenses as low as 16 arc-minutes can be tolerated but are not recommended. The decrement in legibility when symbol subtense is reduced from 22 to 16 minutes of arc is about 17 percent in symbol reading rate. VanderKolk, Herman, and Hershberger$^{\text{ref. }3}$ subsequently conducted relevant laboratory studies and concluded that the above data, although intended for stroke-written symbology, were equally applicable for other techniques of symbol construction such as dot-matrix and presumably segmented symbology.

Number of Symbol Elements

This subject has already been discussed in connection with Matrix Type and the reference to the studies of Stephenson and Schiffler$^{\text{ref. }2}$ who found no improvement in the legibility of segmented symbology when the number of segments exceeded sixteen. This also is generally agreed to be a lower limit with legibility decreasing sharply below this number. Similar findings for dot-matrix symbology were reported by Shurtleff$^{\text{ref. }1}$ which indicated that legibility did not improve when the number of dots used to

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[7] Streeter, E., Weber, J.W., and Opittek, E.W., Master Monitor Display Study, Hughes Aircraft Company, P73-464, January 1974.

construct a symbol exceeded 35 (5 x 7 array). This number is also a lower limit with legibility degrading with smaller matrices such as 3 x 5 arrays.

Contrast and Surround Luminance

It is generally accepted that the adaptation level of the eye is a critical parameter in the perception of visual images. In display applications, it is often the case that the adaptation level is established by the display surround luminance. By this means the display surround luminance either directly or indirectly determines the number of gray shades the eye can detect. An alphanumeric symbol requires the detection of two shades of gray, and the contrast required for this task can be readily determined from established data. Also affecting the perceived brightness of symbols is symbol subtense, stroke width, and additionally, in the case of dot-matrix displays, the percent active area. This latter factor is the primary differential effect operating on perceived brightness when comparing segmented and dot-matrix symbology. For example, the data of VanderKolk, Herman, and Hershberger$^{\text{ref. } 3}$ indicate that for an eye adaptation level and symbol surround luminance of 500 foot Lamberts and a symbol subtense of 30 arc minutes, the total required symbol luminance for comfortable viewing of segmented symbology (100 percent active area) would be 600 foot Lamberts including the 500 foot Lambert reflected ambient illumination. This represents a contrast of 0.2. The VanderKolk$^{\text{ref. } 3}$ studies also demonstrated the relationship between the percent active area of dot-matrix displays and emitter luminance. A dot-matrix display with equal emitter size and inter-element gaps, for the same conditions as the segmented display above, would require a symbol element luminance of 1500 foot Lamberts for viewing symbology comfortably. This represents a contrast of 2.0 or a 10:1 increase over the segmented symbology.

Conclusions and Recommendations

It is apparent that for the Programmable Panel symbolic display, the two primary overriding factors in the selection between a dot-matrix and a segmented character format is the reduction in electronic complexity without loss of legibility and the reduced contrast requirements offered by the 16 segment (starburst) format.

After giving due consideration to all of the relevant tradeoff data affecting legibility of the alternate fonts, it appears that the 14 segment alphanumeric display is superior to the dot-matrix display for this application.

PROGRAMMABLE PANEL DESIGN

The programmable panel hardware is comprised of two units as shown in the block diagram, Figure 6.

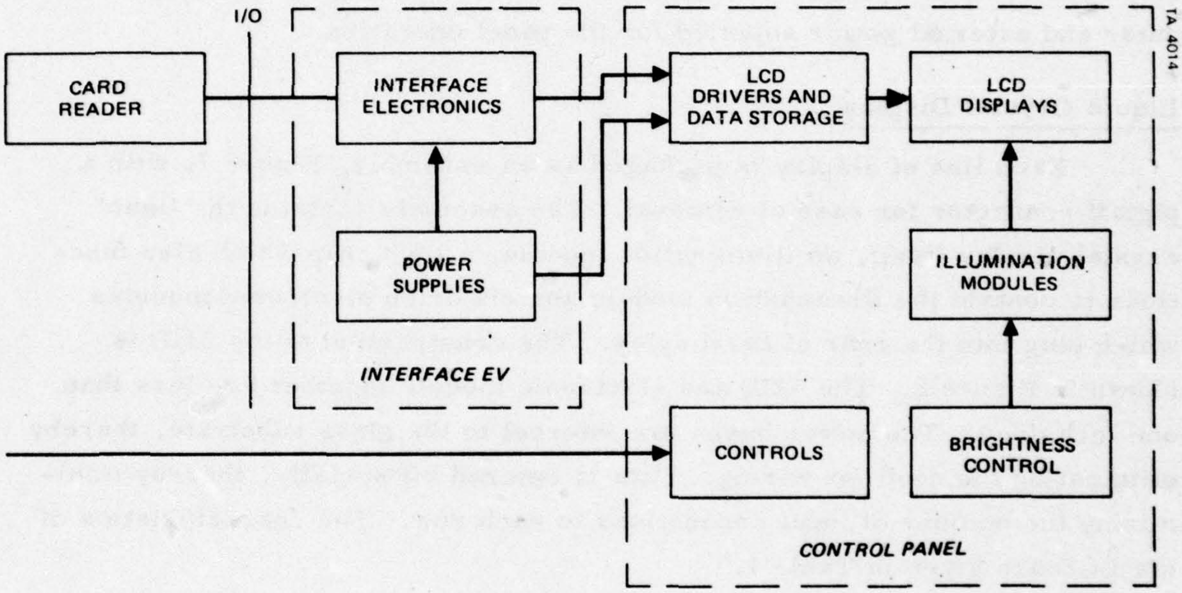

Figure 6. Programmable panel block diagram.

The control panel itself contains four rows of liquid crystal alphanumeric displays as shown in the hardware photograph, Figure 1. Each row of liquid crystal display contains 24 characters. It is the intent of the configuration to associate characters in groups of 4 with a push button located directly below the 4 characters. Each row of liquid crystal display contains its own individual light trap required for contrast enhancement and an illumination module for viewing the display in a low ambient environment. In addition, each LCD row has its own driver and data storage electronics. The electronics are contained on small modules which plug into the back of the display rows. A brightness control on the front panel is provided for controlling the illumination modules. Two rows of controls comprised of

5 push buttons each are provided. In the current configuration, the push buttons are inactive. The outputs of the controls are provided at the I/O connector and can be used to provide pilot communications to a computer to indicate display and/or mode selection.

The interface electronic unit (IEU) contains two circuit boards. The first board contains the interface electronics needed to reformat the output of a Hickok 960A 80 column card reader for compatibility with the LCD drive electronics. The second circuit board contains two power supplies required for both the interface electronics and the LCD drive electronics. In a system operation, the programmable panel can interface directly with a computer and external power supplied for the panel operation.

Liquid Crystal Display

Each line of display is packaged as an assembly, Figure 7, with a pigtail connector for ease of removal. The assembly contains the liquid crystal display itself, an illumination module, a light trap which also functions to contain the illumination module and six drive electronic modules which plug into the rear of the display. The construction of the LCD is shown in Figure 8. The LCD and electronic module together are less than one inch deep. The power buses are internal to the glass substrate, thereby eliminating the need for wiring. Data is entered bit serially, thereby minimizing the number of input connections to each row. The characteristics of the LCD are given in Table 1.

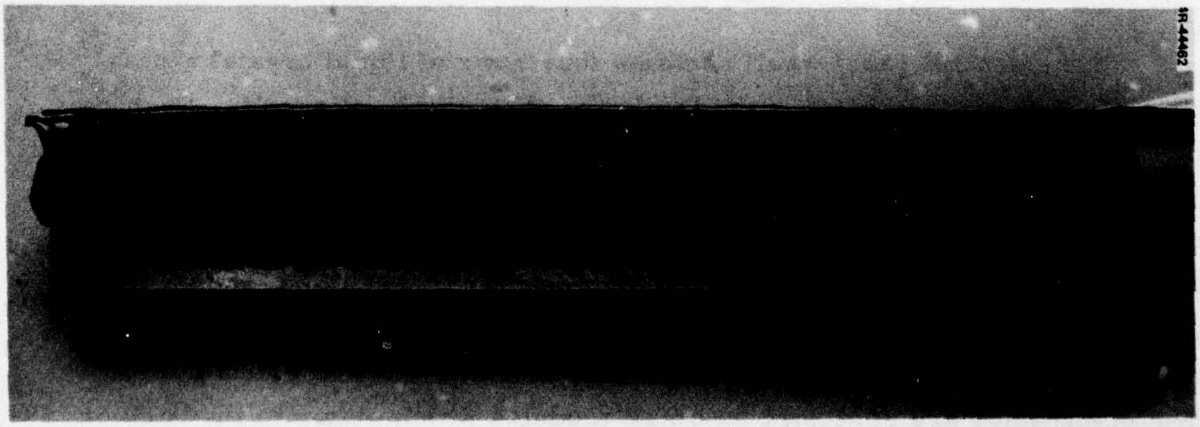

Figure 7. LCD line assembly.

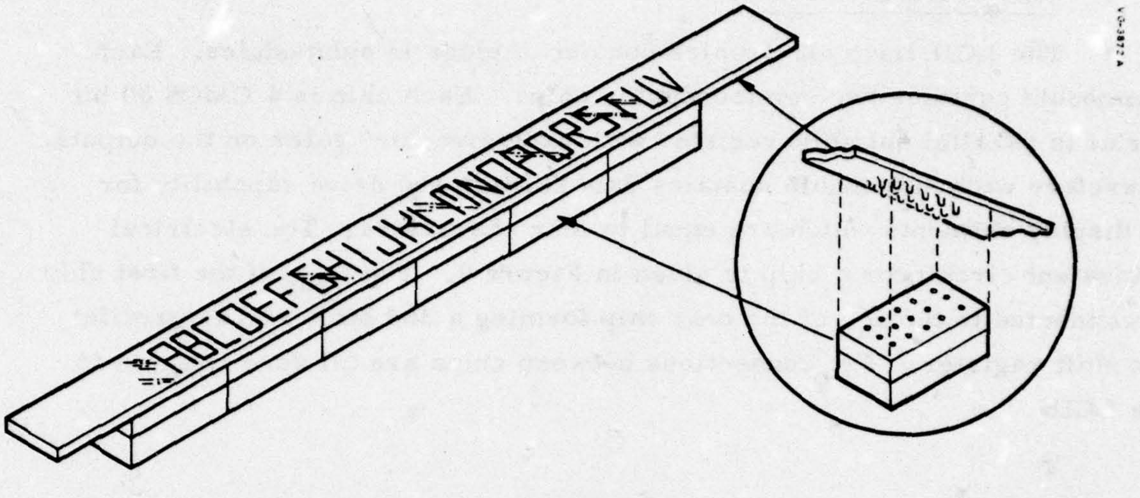

Figure 8. LCD construction.

TABLE 1. LCD CHARACTERISTICS

LC TYPE	dynamic scattering, reflective
Characters Per Row	twenty-four
Character Height	0.325 inch (5/16 inches)
Character Width	0.195 inch
Character Spacing (center to center)	0.245 inch
Row Spacing (center to center)	0.625 inch
Stroke Width	0.0375 inch (maximum)
Font	14-segment starburst
Power (operating)	6 MW all segment on (1.4 uw/seg)
Power (lighting)	5V
Contrast	20:1 minimum
Interface	+5 to -9V serial digital
Operating Temperature	-55°C to +80°C
Storage Temperature	-55°C to +125°C
Rise Time (at 25°C)	15 msec (10-90 percent)
Fall Time (at 25°C)	250 msec (10-90 percent)
Heaters	provided for improved rise and fall time, if required

LCD Drive Electronics

The LCD drive electronics consist of plugs in submodules. Each submodule contains two semiconductor chips. Each chip is a CMOS 30 bit serial in parallel out shift register with exclusive "or" gates on the outputs. Therefore each submodule contains data storage and drive capability for 60 display elements which are equal to four characters. The electrical equivalent circuit for a chip is given in Figure 9. The D_{out} of the first chip is connected to the D_{in} of the next chip forming a 360 bit serial in parallel out shift register. The connections between chips are all done internal to the LCD.

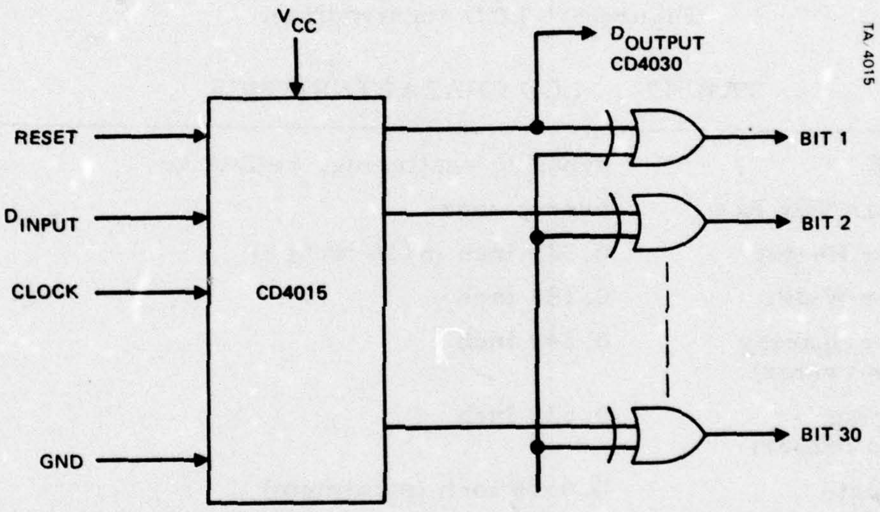

Figure 9. LCD drive electronics equivalent circuit.

Lighting Module

The LCD emits no light of its own. Consequently an external light source is required for viewing the display in low ambient illumination. Alternate lighting techniques were explored. These included wedge lighting, end lighting, edge lighting and direct lighting.

The evaluation criteria included brightness uniformity, power consumption, reliability and simplicity of mechanization. This evaluation led to the development of a plastic light bar containing ten low power miniature lamps. The light bar contains ten miniature prisms. Each lamp is placed between two prisms as shown in Figure 10. The ten prisms capture the

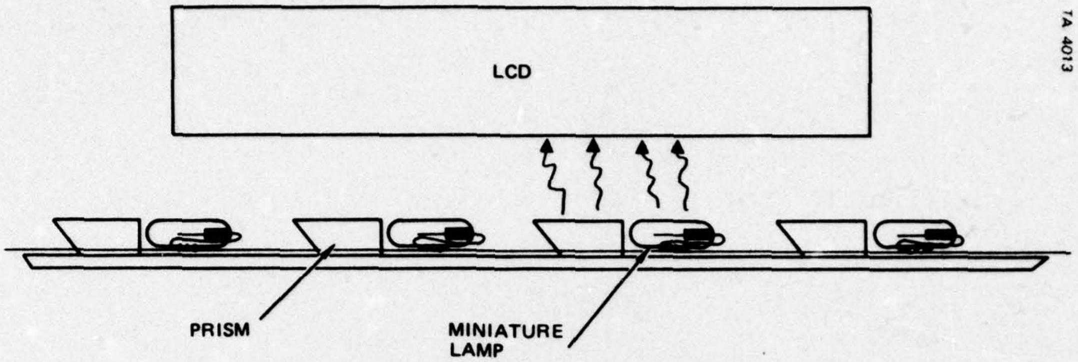

Figure 10. LCD lighting mechanization.

forward scattered light and direct it up into the edge of the display, creating a uniform light source.

Interface Electronics

The interface electronics unit, Figure 11, contains two plug in cards, A1 and A2. One of the plug in cards, A2, contains the DC power supplier required for operation of the interface electronic unit, MMD and card reader. The second plug in card, A1, contains the interface electronics itself.

The interface electronics unit function is threefold. First, it converts the output of the card reader which is in the Hollerith code, to the code required by the MMD liquid crystal display. Second, it provides the timing and control required for display row, and character selection. And, third, it provides the +5 V and -12 V DC regulated power required for the liquid crystal display.

Circuit Description

A schematic diagram of the interface electronics card, A1, is shown in Figure 12. The 12 bit parallel Hollerith code received from the card reader is compressed to 8 bits by U18A through U18E, U17A, U17B and U10B. These 8 bits address PROMS U19 and U20 which convert the compressed Hollerith code to the 15 bit code required by the liquid crystal display (LCD). The outputs of U19 and U20 (15 bits) are parallel loaded into the shift registers U21 and U22 and clocked out bit serially into U23 which converts the 0 to 5 V data to -12 to +5 data.

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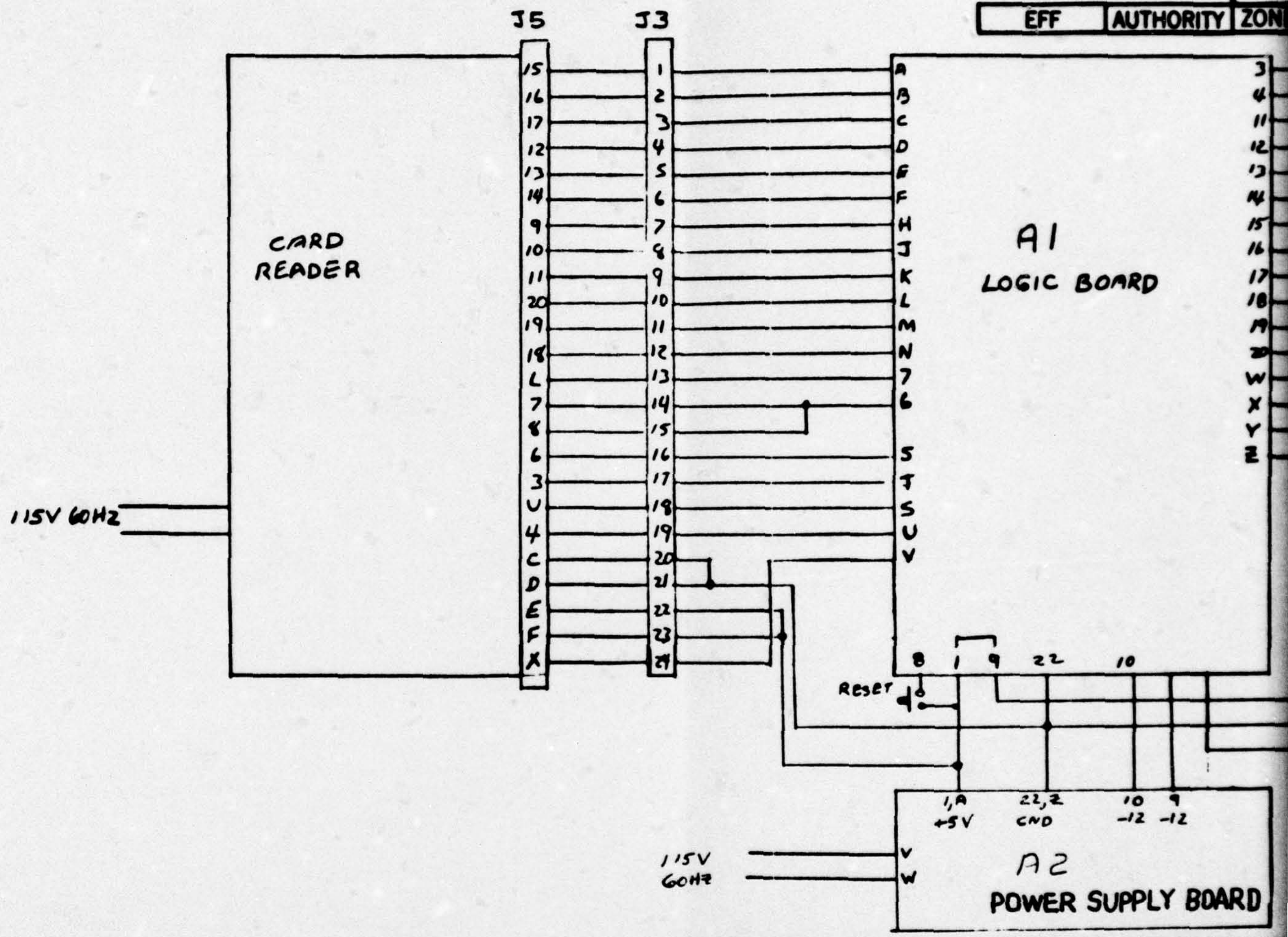

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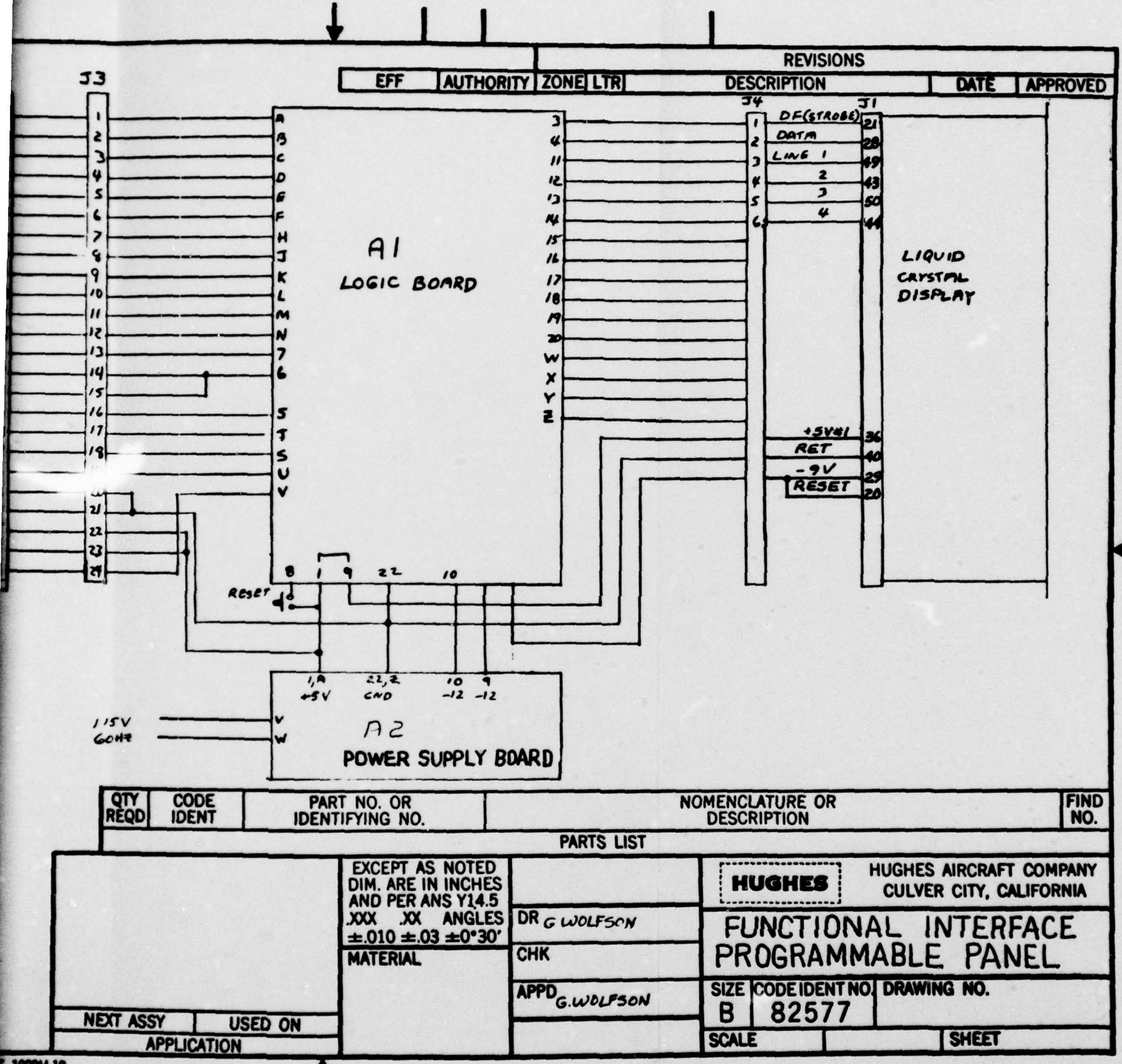

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FUNCTIONAL INTERFACE PROGRAMMABLE PANEL

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Figure 11. MMD functional interface.

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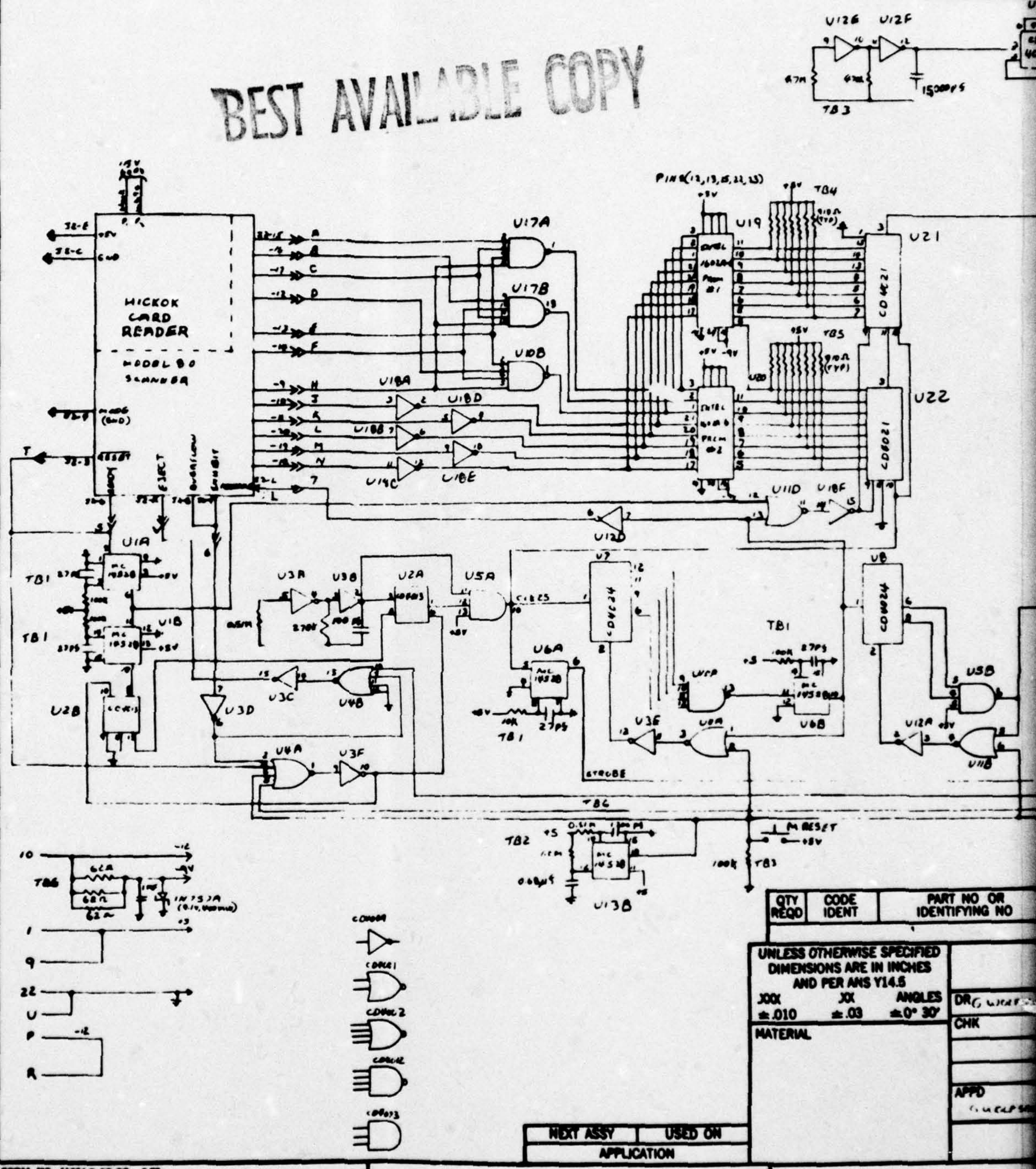

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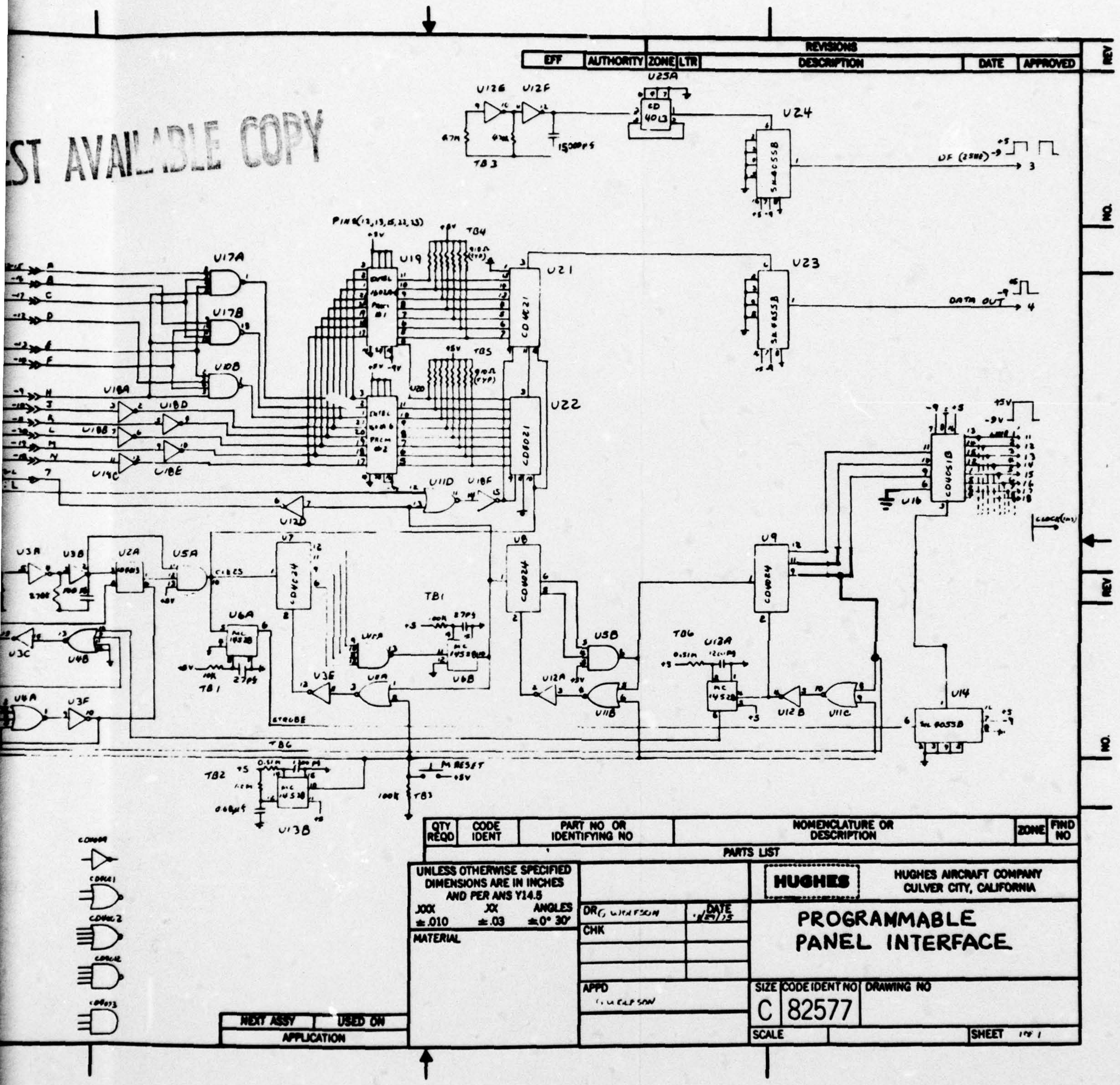

Figure 12. Programmable panel display interface.

2

U12E, U12F and U25A function is a 25 KC oscillator to provide the AC switch drive to the LCD. The output of the oscillator is converted from a 0 to 5 V square wave to a -9 to 5 V square wave by U24.

The remainder of the circuitry shown on the schematic provides the timing and control. When a tab card is inserted into the card reader and accepted, a ready signal is received and delayed by the one shot U1A. The output of U1A is used to parallel load the first column of card data into the shift registers U21 and U22. The ready signal is further delayed by the one shot U1B whose output turns on flip-flop U2B. The output of U2B controls the gated clock formed by U3A, U3B, U2A and U5A. This gated clock (CLK 25) is the heart of the timing function. CLK 25 shifts out the 15 bit data code from U21 and U22 Counter U7 counts down the 15 bits of data (one character) and resets itself. Counter U8 counts the number of characters and resets itself after counting 24 characters (one display line). Counter U9 counts the number of lines, 1 through 4 and resets itself and also turns off the gated clock after the 4th line. U9 controls the demultiplexer U16 by selecting one of 4 lines to output the clock on. The output clock is generated by delaying CLK 25 and level shifting the 0 to 5 V signal to -12 V to +5 V by U14.

All active circuit components with the exception of the PROMS, U19 and U20, are low power CMOS. The PROMS are Silicon Gate MOS devices.

A timing diagram showing the phase relationship of timing and control signals is shown in Figure 13. Table 2 is a components parts list and Fig-14 shows the components layout on the plug in circuit board.

Data Input and Programming

Information is inputted to the Programmable Panel system via 80 column tab cards and a Hickok 960A static card reader. The columns must be encoded with information in the Hollerith code. The Hollerith codes for all alphanumerics (A through Z and 0 through 9) will result in the corresponding character being displayed on the Panel. The Hollerith code and the resulting display symbol is given in Table 3 for all other special symbols.

To program the display via the punch cards, some understanding of the display architecture is required. A full display consists of 4 lines of characters with 20 characters per line. However, the programmer should think of each display line as containing 24 characters (rather than the 20 that

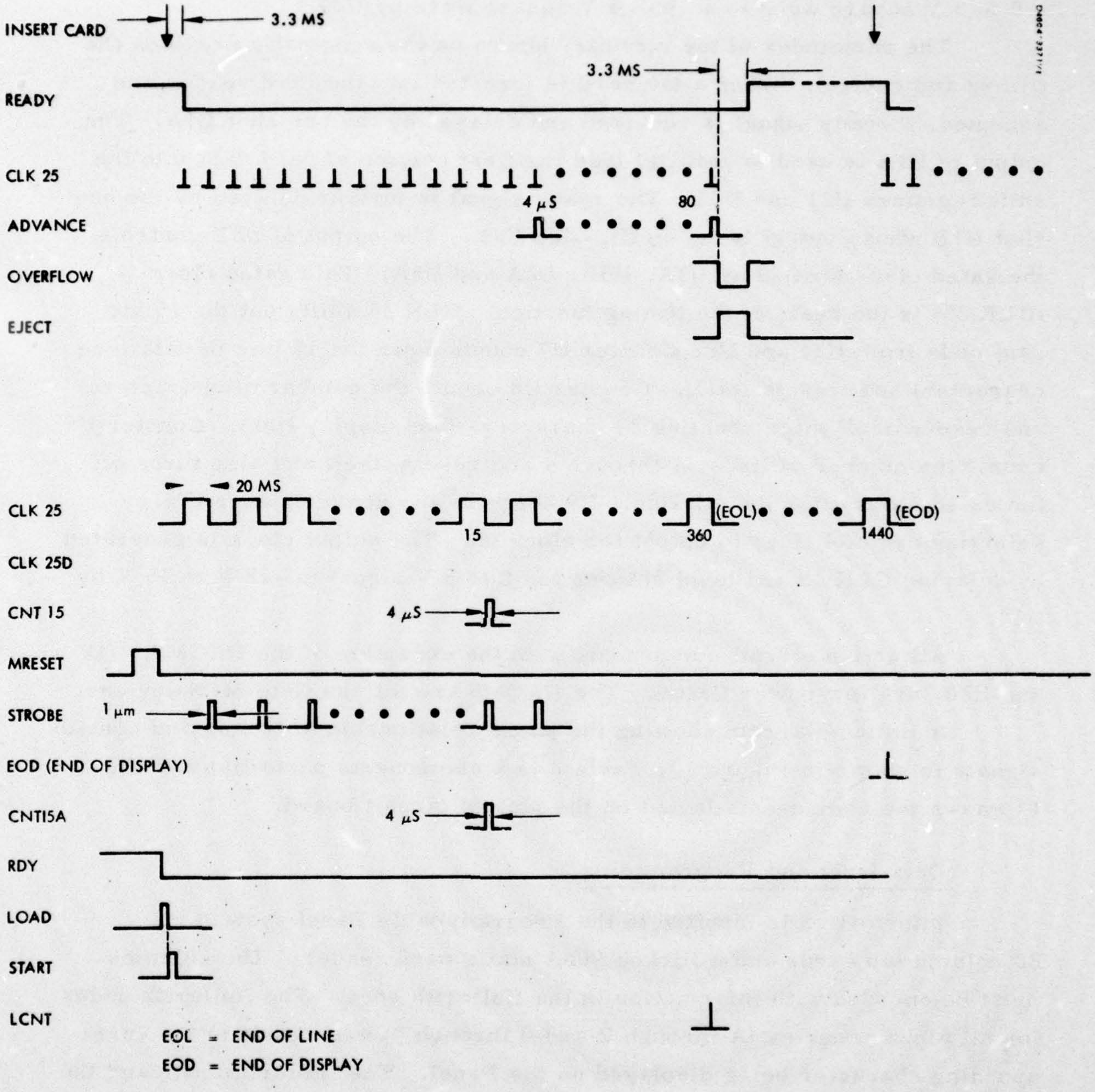

Figure 13. Timing and control signals.

TABLE 2. PARTS LIST, MASTER PROGRAMMABLE PANEL DISPLAY INTERFACE

Quantity	Part	Description	Manufacturer	Designation
1	CD4001	NOR Gate	RCA	U11
1	CD4002	NOR Gate	RCA	U4
2	CD4012	NAND Gate	RCA	U10, U17
2	CD4013	D-Flip Flop	RCA	U2, U25
2	CD4021	Shift Register	RCA	U21, U22
3	CD4024	Binary Counter	RCA	U7, U8, U9
3	CD4049	Buffer	RCA	U3, U12, U18
1	CD4073	AND Gate	RCA	U5
3	MC14528	One Shot	Motorola	U1, U6, U13
1	SIL4051B	Demux	Siltex	U15, U16
3	SIL4055B	LCD Driver	Siltex	U14, U23, U24
2	1602A	PROM	Intel	U21, U22
1	1N757A	Zener, 9.1 V, 400 MW		TB6
2	62 ohm	Resistor, 1/4 Watt		TB6
16	910 ohm	Resistor, 1/4 Watt		TB4, TB5
1	10 K	Resistor, 1/4 Watt		TB1
4	100 K	Resistor, 1/4 Watt		TB1
1	0.27 M	Resistor, 1/4 Watt		TB3
1	0.47 M	Resistor, 1/4 Watt		TB3
3	0.51 M	Resistor, 1/4 Watt		TB3, TB6
1	1.0 M	Resistor, 1/4 Watt		TB2
1	4.7 M	Resistor, 1/4 Watt		TB3
1	15 pF	Capacitor		TB3
4	27 pF	Capacitor		TB1
2	1200 pF	Capacitor		TB6
1	0.033 MF	Capacitor		TB3
1	0.68 MF	Capacitor		TB2
1	1.0 MF	Capacitor		TB6

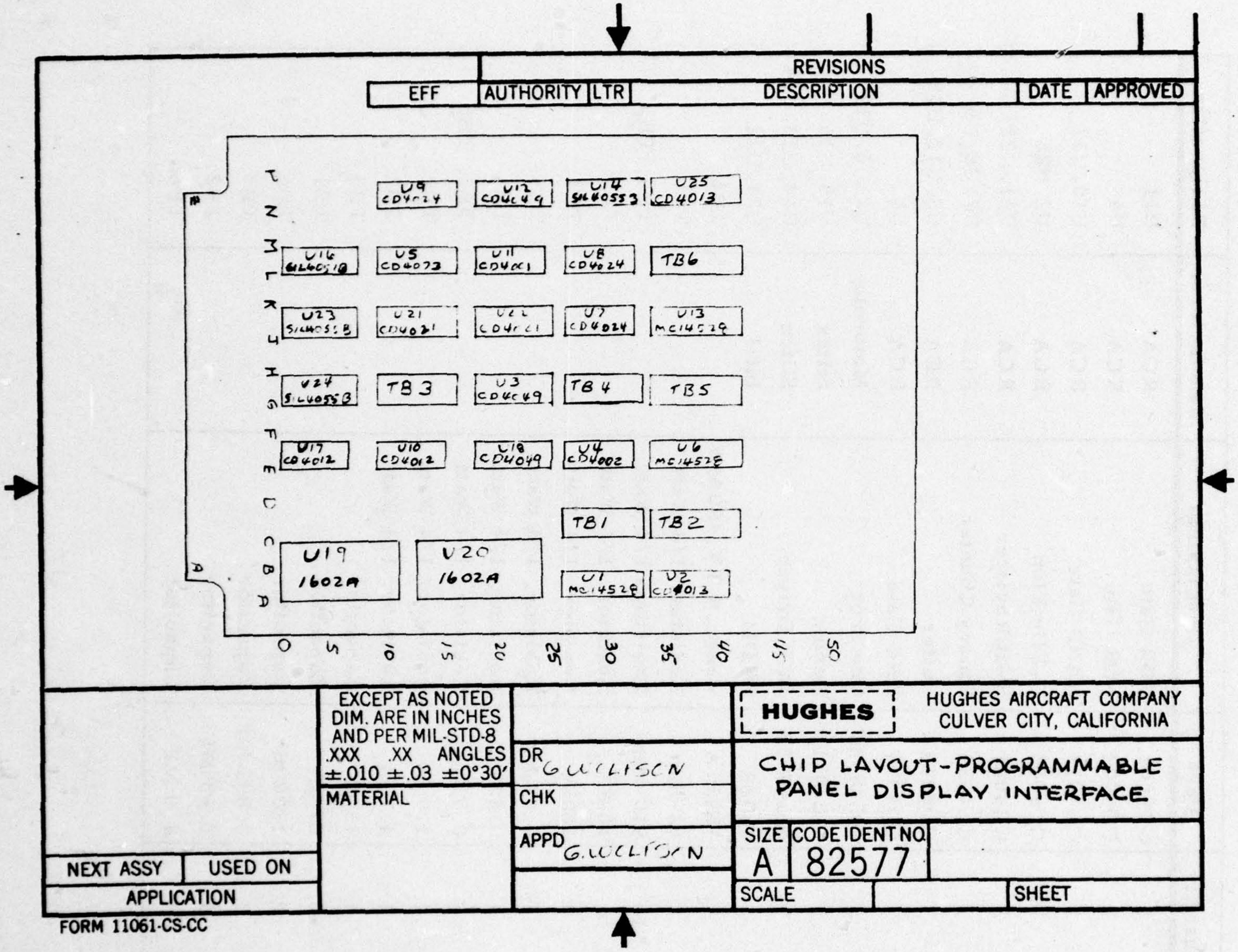

Figure 14. Chip layout – MMD flat panel display interface.

TABLE 3. CODES FOR SPECIAL SYMBOLS

Hollerith Code	Displayed Symbol
'	⧆
,	✓
%	→
–	◂
>	_
:	△
#	▱
+	+
)	‾
=	=
/	/
?	_

actually exist with the first two and last two characters not viewable. Therefore, to program the entire display a total of 24 x 4 = 96 characters must be entered. Since each tab card contains 80 columns, a total of 2 cards are required for programming. Data is entered sequentially from left to right starting with the first line. The tab card column and corresponding displayed character is shown in Table 4.

TABLE 4. TAB CARD/DISPLAYED CHARACTER

	Column											
	1	2	3	4	5	6	7	8	9	10	11	12
Card-1	X	X	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10
Card-2	4/7	4/8	4/9	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18

	Column											
	13	14	15	16	17	18	19	20	21	22	23	24
Card-1	1/11	1/12	1/13	1/14	1/15	1/16	1/17	1/18	1/19	1/20	X	X
Card-2	4/19	4/20	X	X								

	Column											
	25	26	27	28	29	30	31	32	33	34	35	36
Card-1	X	X	2/1	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10

	Column											
	37	38	39	40	41	42	43	44	45	46	47	48
Card-1	2/11	2/12	2/13	2/14	2/15	2/16	2/17	2/18	2/19	2/20	X	X

	Column											
	49	50	51	52	53	54	55	56	57	58	59	60
Card-1	X	X	3/1	3/2	3/3	3/4	3/5	3/6	3/7	3/8	3/9	3/10

	Column											
	61	62	63	64	65	66	67	68	69	70	71	72
Card-1	3/11	3/12	3/13	3/14	3/15	3/16	3/17	3/18	3/19	3/20	X	X

	Column							
	73	74	75	76	77	78	79	80
Card-1	X	X	4/1	4/2	4/3	4/4	4/5	4/6

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