

DESIGN AND DEVELOPMENT OF A PROTOTYPE SYSTEM PERFORMANCE EVALUATION CONSOLE (SPEC)

FINAL REPORT

MAY, 1970

GENERAL  ELECTRIC
APOLLO SYSTEMS
HOUSTON PROGRAMS
HOUSTON, TEXAS

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CHECKOUT SYSTEMS

FINAL REPORT

DESIGN AND DEVELOPMENT OF A PROTOTYPE
SYSTEMS PERFORMANCE EVALUATION CONSOLE.

(SPEC)

MAY, 1970

COLOR ILLUSTRATIONS REPRODUCED
IN BLACK AND WHITE

"This document was prepared for the
National Aeronautics and Space
Administration under Contract NAS9-9582.
Article XVIII Paragraph B"


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NASA S-70-31899

SPEC Console

Typical Color CRT Displays

NASA S-70-36541

Typical Control Display
Presentation

1.0 INTRODUCTION

This report was prepared under Contract NAS 9-9582 by the General Electric Company, Houston, Texas, to summarize the design and development of the Systems Performance Evaluation Console (SPEC). This work began June 20, 1969 and resulted in delivery to the NASA Manned Spacecraft Center, Houston, Texas, of a prototype SPEC on April 14, 1970 and a subsequent delivery of a documentation package on May 25, 1970.

It was the objective of this contract to develop an engineering feasibility model which demonstrates the capability of selective data processing and presentation, decision oriented displays, rapid display reconfiguration, and variable function entry.

The SPEC is a versatile control and display console which provides an efficient man/machine interface between the console operator and the system under test or checkout. This report contains a description of the console and provides an indication of results and conclusions.

2.0 SYSTEM CAPABILITIES

The brief discussion which follows highlights the SPEC system capabilities. Additional description is contained in Paragraphs 3.0 and 4.0.

DATA ACQUISITION

Up to 200 test parameters out of a maximum of 4096, can be acquired from address tagged data streams in any one of four different formats.

Addition and/or deletion of address from a given parameter list is achieved by keyboard entry.

DATA PROCESSING

Computer processes acquired data and handles operator initiated uplink commands or display modification commands.

Four fixed display pages, any one of which can be modified and saved, are available for display.

Boolean operations involving up to 5 discretes are possible.

DATA DISPLAYS

Fixed display pages consisting of 25 display lines/page can be presented on either of two 17" color TV monitors or both.

The 25 display lines/page may be used to display:

Annotated analogs with upper and lower limits with red, green, or yellow color controlled by hardware.

Annotated analogs with upper limits only, lower limits only, or no limits with color selected from white, red, green, blue, cyan, magenta, or yellow by software.

Three annotated discretes on each display line with the color of each discrete specified by software and selected from black, white, red, green, blue, cyan, magenta, or yellow.

Up to 30 alpha-numeric characters on each line as selected from a 64 character repertoire.

Any combination of the preceding to provide two unique displays simultaneously.

Real time and historical trend, scaled in time for 5 seconds to 15 minute plots, with automatic ordinate scaling can be presented in black and white in any of three formats:

- Moving Window
- Fixed interval
- Repeated interval

EXTERNAL VIDEO

The monitors can be switched to present:

- Closed Circuit TV
- Film data (35 mm slides)
- Commercial Broadcast TV

All monitor video inputs can be switched to a remote and/or a hard copy device.

KEYBOARD AND CONTROL DISPLAY

A stroke writing CRT with 64 characters/line and 16 lines is provided for verification of operator initiated commands.

For command entry and control, the keyboard provides:

- Standard typewriter keys
- Fixed function keys
- 35 Variable function keys with overlays for generation of 4000 possible unique commands.

3.0 SYSTEM DESCRIPTION

3.1 System Functional Description

The block diagram shown in Figure 3.1-1, illustrates the major elements within SPEC and the relationship between SPEC and the system under test.

Test functions, originating at the keyboard, are forwarded through the SPEC Processor to the system under test for execution. Measurement information obtained from the system under test arrives at the Data Acquisition Device (DAD) in the form of digital addressed data.

The DAD receives incoming data and, under program control, directs only selected measurands to storage areas within the processor memory. Once in a storage, these measurands are accessible to the SPEC Processor. Processing the stored data which has been selected for display consists of one or more of the following:

- Converting to engineering units
- Averaging analog (meter) data
- Limit checking analog data
- Boolean function development
- Analog display development
- Event display development
- Trend display development

The computer output, in digital form, is translated into drive signals for display generation and then into video signals for application to color monitors.

The visual symbols employed to represent a measurand are either a color bar, a color patch, or a trend line. These symbols, along with alphanumeric (A/N) annotation, form the composite display presentation. Figure 3.1-2 is an example of these displays.

One analog (or meter type) display uses a horizontal bar where the length is proportional to the value of the measurand and the color of the bar indicates measurand status. This type of display utilizes fixed colors as follows:

Red = out of tolerance (high or low)

Green = in tolerance

Yellow = marginal (high or low)

This type of meter bar contains fixed vertical dividing lines representing tolerance limits.

A second type of meter display utilizes programmable bar colors and tolerance limits.

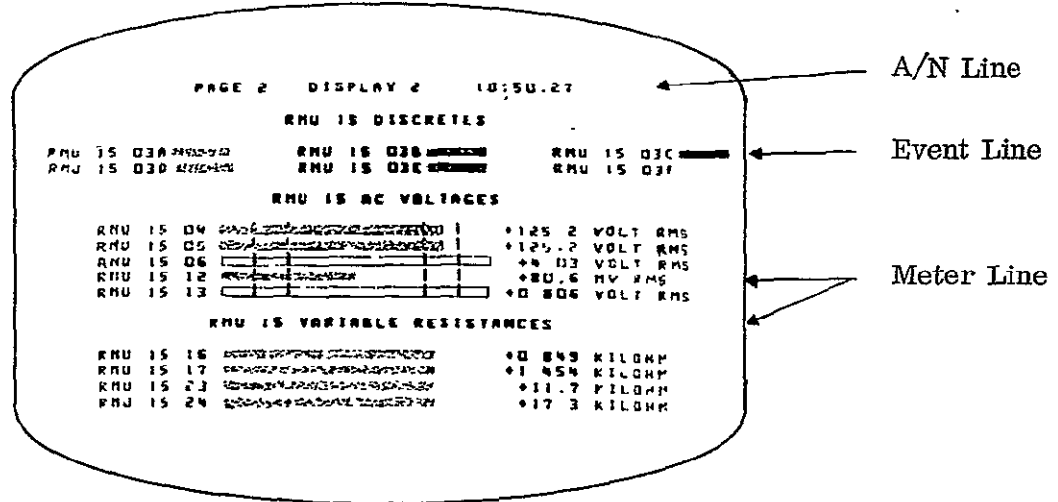
Discrete (or event type) information is displayed as a horizontal patch in which the programmed color indicates the event status (i.e., on, off, in process, No-Go).

The parameters to be displayed are programmed into as many as four pages. These fixed pages, which may contain a mixture of analog and discrete parameters, can be altered by the operator during test by adding or deleting parameters as dictated by test requirements.

In addition to these fixed pages (and one modified page), the operator can select a plot wherein any desired parameter is displayed in graphical form. Thus the operator can obtain trend information by observing a parameter variation as a function of time.

NOT REPRODUCIBLE

Meter-Event Display



Trend Display

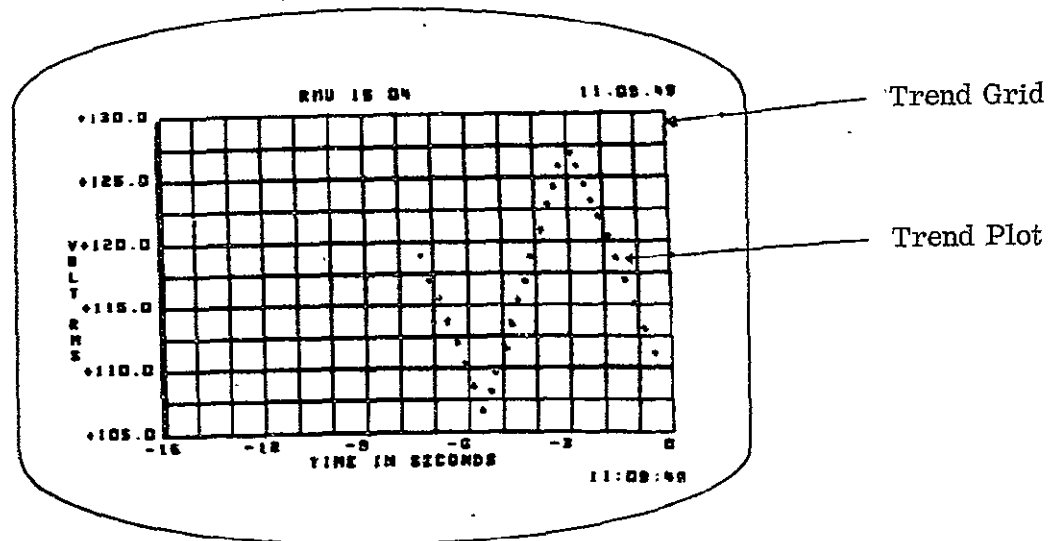


Figure 3.1-2

The same display devices are also used to display information stored on film, such as schematics and reference documentation, as well as live pictures transmitted through CCTV, or standard broadcast media.

A hard copy of the same data which is presented on the TV display is available to the operator within seconds, by utilization of a hard copy device which operates from the video input.

To maintain efficient communication between the operator and the console, SPEC employs a control display and a keyboard.

The operator communicates with SPEC through the keyboard and SPEC responds via the control display. The control display is tutorial in that SPEC will ask the operator a question and the operator provides the answer. In addition to communications, the control display is also used for presentation of special information such as memory dumps, results of computations, and critical conditions.

The keyboard is multi-function, employing both fixed function and variable function keys. The fixed function keys include all standard alpha-numeric characters plus special control keys. The variable function keys are assigned specific functions as a result of a coded overlay and the appropriate software program.

The operator maintains control by initiating test routines and by selecting the required displays to monitor results.

3.2 Hardware Description

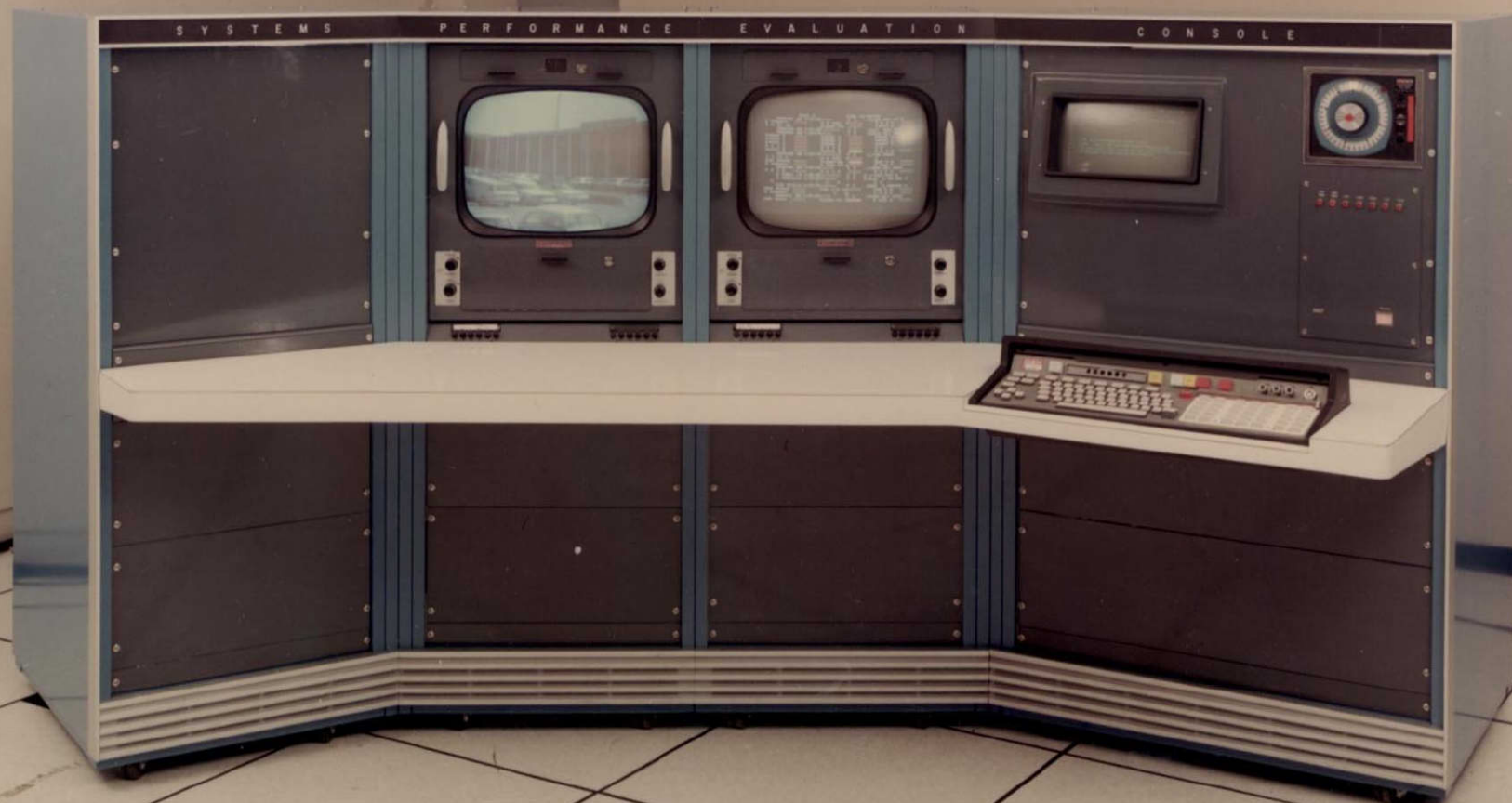
The SPEC Console consists of four standard low boy type cabinets plus a work surface as shown in the attached photograph (NASA S-70-31899). The overall dimensions of the console are approximately 118"W x 58"D x 55"H including the work surface. The console is painted blue with dark grey front panels and white textolite work surface. Since the console is designed to be manned by one operator and possibly one observer, the keyboard and displays are arranged accordingly.

The right most bay (A4) contains the keyboard and control display which are parts of a modified Univac Display Unit (Uniscope 300). These components are interfaced with the computer through logic contained in the Display Generation Enclosure located in the left most bay (A1). The Data Acquisition Device (DAD) which facilitates console digital data input, is located in the lower portion of the A4 bay. In addition, a remote control unit, for a Kodak Carousel slide projector, and console power controls are located on the front panel.

The DAD which is constructed primarily of Honeywell logic (DTL) cards, selects parameters from the incoming data stream under program control and stores the data in the Control Data Corporation (CDC) 169G shared memory. Direct access connections to the memory which is located external to the console, and input data cables, enter the DAD chassis through the bottom of the A4 bay.

The two center bays (A2 & A3) each contain a 17" Conrac color TV Monitor: Video switching to permit operator selection of six channels (includes 3 data, 1 film, and 2 CCTV) for internal or external viewing; a Grass Valley Group Video and sync distribution amplifier assembly; and a General Electric Color Encoder. In addition, one of the bays (A2) contains a Tektronix Scan Converter used to develop the trend display.

NASA
S-70-31899



A CDC 160G computer is utilized to perform data processing and executive control for the console. This computer utilizes 13 bit words and a 1.35 microsecond memory cycle. The computer plus a shared memory and a CDC 171G I/O Unit emulate the function of the SPEC processor but are not physically located in the console.

The left most cabinet (A1) contains the Display Generation Enclosure and space which is allocated to a future processor. Through direct memory access connections, the Display Generation Enclosure obtains the data which is to be displayed. Appropriate formats and A/N characters are generated and combined with data which is then converted to video signals. General Instruments Read Only Memories (ROM's) are used to store the A/N characters. The Display Generations Enclosure also interfaces with the computer through two I/O channels.

One channel accommodates the keyboard and the Control display with parallel-to-serial conversion, special signal conversion circuits, and the required control signals. The second channel is utilized to transfer digital data for trend plots. This data is transformed to analog and supplied to the scan converter, in the A2 bay, as X axis and Y axis deflection signals. Two digital-to-analog converters, built by Analog Devices, are used in this process. In addition, the Display Generation Enclosure contains an Accutronics crystal-controlled oscillator and all the time decoding required to generate the raster TV display.

The Display Generation Enclosure logic is built using dual-inline packages (DIP's) mounted on Augat hi-density wire wrap boards. Both Sylvania and Texas Instruments integrated circuits (TIL) are used.

All required DC power supplies are contained within the console. The console, exclusive of the SPEC Processor, consumes approximately 1000 Watts at 115 VAC.

Each bay of the console is provided with a blower mounted at the bottom. Air is exhausted through grilles located in the top of each rear door.

The basic cabinet structure, which is furnished by Cabtron, is mounted on casters for mobility. All major internal components are slide mounted on hinges to provide easy access for maintenance.

3.3 Software Description

In order to demonstrate the capabilities of SPEC and to provide for an effective means of acceptance testing, the following two computer programs were developed:

SPEC Pre-Operational Program (PRE-OP)

SPEC Operational Systems Program (OPS-SYS)

Both of these programs are contained on a single magnetic tape and either may be loaded by operator command from the console keyboard. A unique function key overlay is provided for each program.

3.3.1 Pre-Operational Program

The PRE-OP program is basically a console diagnostic which exercises the hardware through all possible modes.

The Data Entry Test verifies the operation of all keyboard functions and then verifies the capability of the control display to present all possible characters in all possible locations.

The Color TV Monitor Test verifies the hardware capability to present analog and discrete data in color in conjunction with color change reference marks (limits) and desired annotations. This test can be conducted entirely automatically or step-by-step based on operator discretion.

The Data Acquisition Device (DAD) Test verifies the capability of SPEC to accept address-tagged digital data from any one of four different sources.

The Trend Display Test verifies the trend plotting capability and permits calibration.

In addition, the PRE-OP program allows the operator to display the contents of any memory location desired.

3.3.2 Operational Systems Program

The OPS-SYS program is a specific implementation of the SPEC Software System wherein a certain set of parameters were assigned to illustrate console operation in performing spacecraft test.

The SPEC Software System is structured and specified in such a way as to accommodate the processing of parameters for any nominal spacecraft subsystem (approximately 200 parameters). In addition, the software was created with the possibility of future conversion to another processor in mind.

The SPEC Software System consists of an Executive Control Program and nine subprograms which are described as follows:

Executive Control Program	Provides main cycle loop for SPEC Processor, process sequence control, and display format control.
Engineering Units Processor Subprogram	Provide conversion of 8 or 10 bit analog data counts to decimal engineering units and proportional meter bar length. Also provides for averaging of up to 10 samples.
Events Processor Subprogram	Provides for processing bi-level discrete from raw data and display of state as a color patch. Also provides state inversion and boolean functions for up to 5 discretes.

Trend Data Processor Subprogram	Provides content format for moving window and fixed interval trend plots. Includes computation and output of ordinate and abscissa annotations; computation of sample rate, sample averaging, and number of points to be plotted; computation of dummy calibration; conversion and display of time.
Command/Verification	Provides function key entry decoding and calls appropriate action agent. Also provides interrogation routine, and maintains interrogation/response/states displays on control CRT.
Data Acquisition Control Subprogram	Provides for modification of DAD control memory for data selection and input. Also provides the core mapping function for data input core.
Trend Data Output Control Subprogram	Provides control of scan converter mode and control of data output to scan converter.
Display Control Subprogram	Provides for modification to annotation in color monitor refresh memory for display format selections.
A/N and Keyboard Control Subprogram	Provides for input of keycodes, assembles messages, and controls output to the control (A/N) CRT.

SPEC/ACE Intercom Control Subprogram	Provides for command and data interface with an ACE-S/C station which is used to simulate a test article interface and a central computer facility.
---	---

Figure 3.3-1 is a functional diagram of the SPEC OPS-SYS software. This diagram indicates the relationship between the various software elements and generally depicts the flow of information and data. Process and format pointers, which are stored in memory, are utilized to construct and refresh memory, the page of data which has been requested for display. The total memory allocation for the SPEC processor is approximately 23K (13 bit words). This is proportioned as follows:

Executive and display Control Software	6K
Data Acquisition Control Software	8K
Parameter storage	4K
Raw Data Storage	4K
Display refresh storage (2 monitors)	.8K
	22.8K

SPEC SOFTWARE FUNCTIONAL DIAGRAM

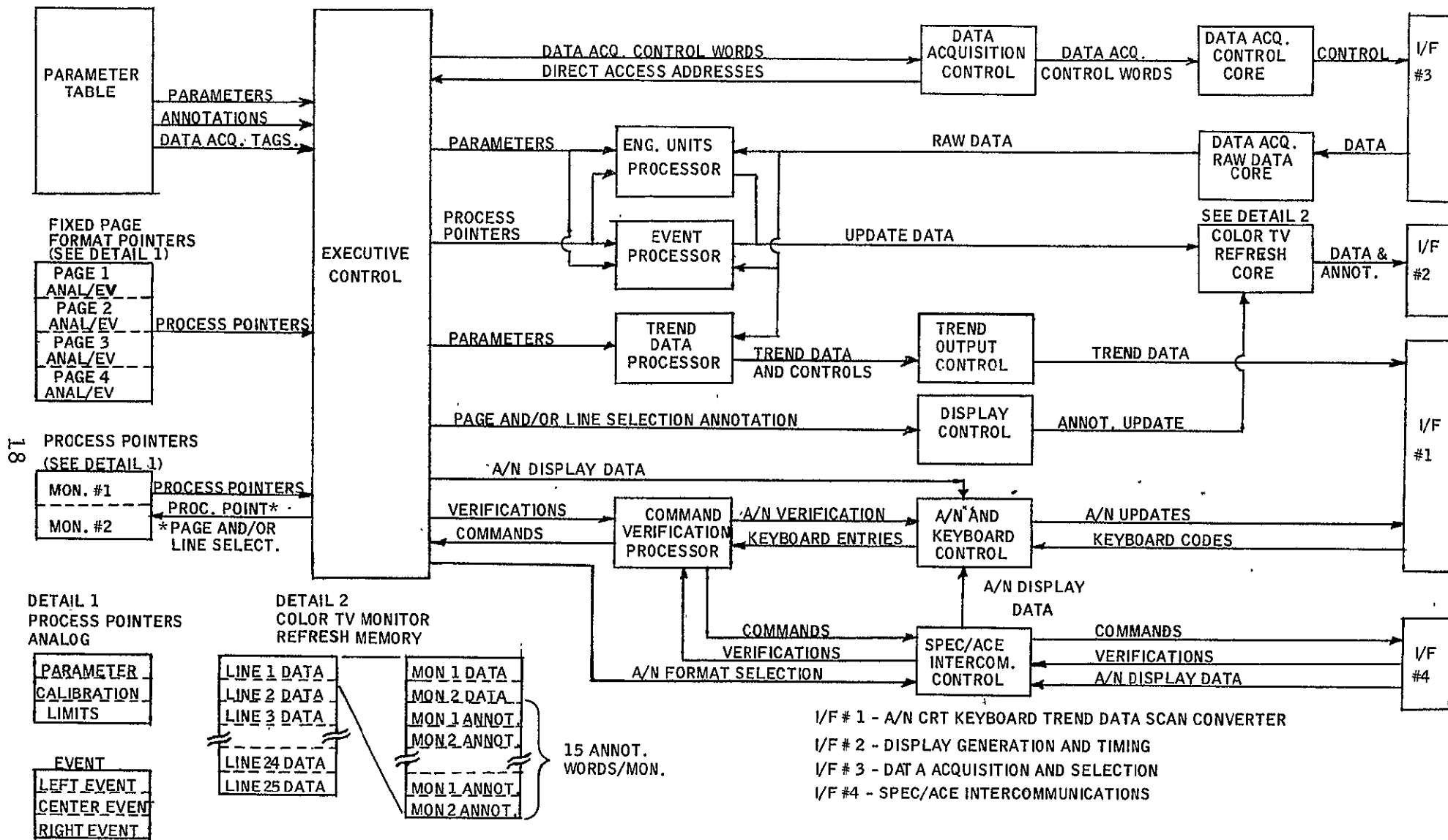


Figure 3.3-1

4.0 SIGNIFICANT DEVELOPMENTS

The SPEC is unique in many respects. The design concepts and innovations which contribute specifically to its uniqueness are considered to be significant developments. The following is a brief description of those developments.

4.1 Alpha-Numeric Character Generation

The SPEC utilizes two different types of character generation. The control display (Uniscopes) characters are stroke written whereas the color TV annotations must be generated line by line as required by the color display formats. In order to generate the raster type characters and maintain the flexibility required to annotate the different displays, special memory devices, interface logic and timing circuitry are required. The following is a brief description of this system which is depicted in block diagram form in Figure 4.1-1.

4.1.1 Memory Selection

Sixty-four 8 x 10 dot matrix characters, consisting of all the Arabic alpha-numerics, some Greek Letters, and special symbols, constitute the repertoire of the color display character generator. To assemble these characters, $64 \times 8 \times 10 = 5120$ bits of permanent memory are needed. In order to minimize the use of processor memory, read only memory (ROM) devices were considered. Metal Oxide Silicon (MOS) technology was chosen for the memory element, primarily for the reason listed below:

- MOS ROM's are extremely small in size - 2048 bits are enclosed in a 24 pin Dual In-Line package (DIP). Only three DIP's are required for storage of all 64 characters.
- MOS ROM's are relatively inexpensive as compared to other methods of implementing the required memory. In minimum order quantity, the ROM's cost about 11¢/bit.

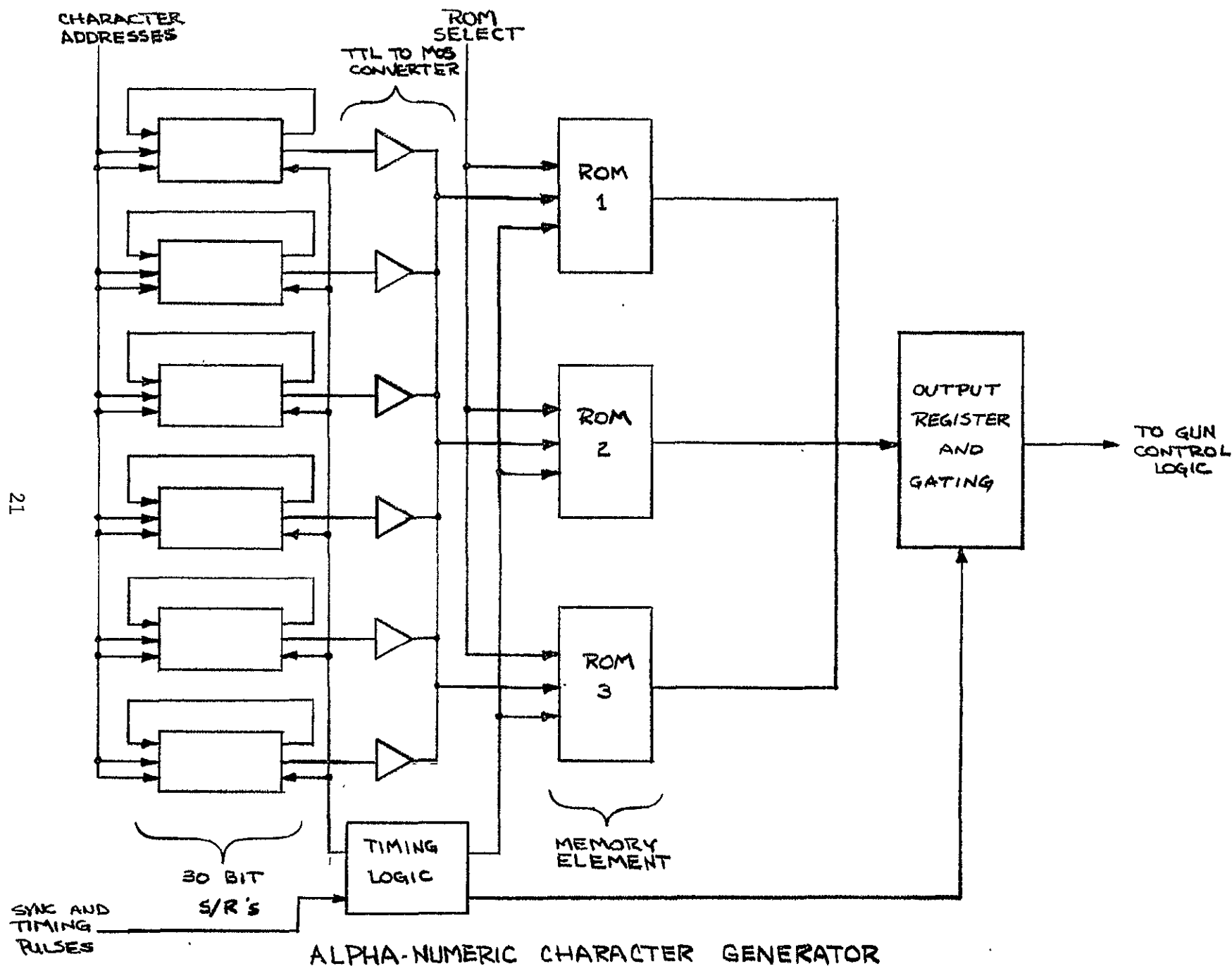


FIGURE 4.1-1

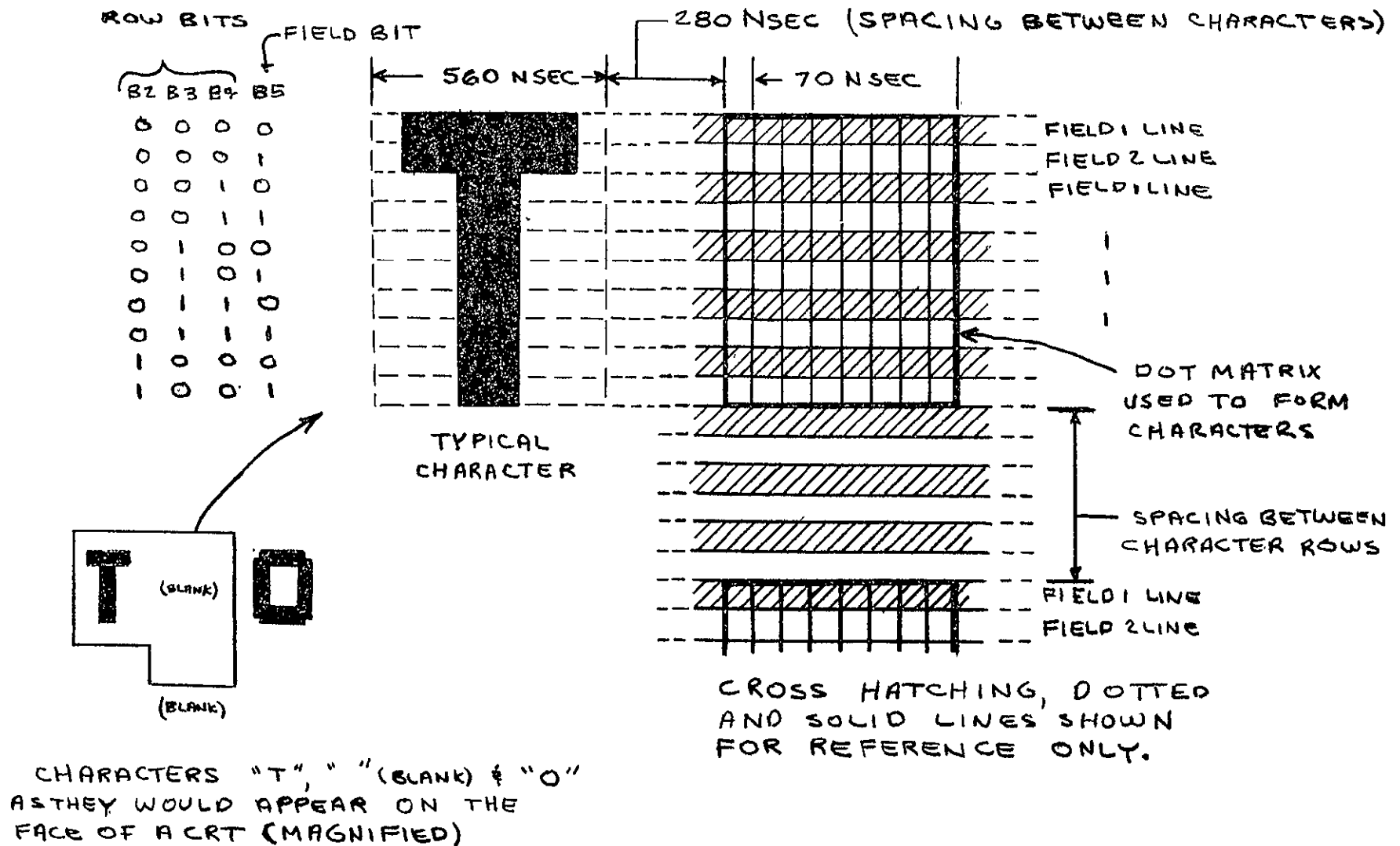
- MOS ROM's have fast decode, access and recycle times. They need no temporary storage as they are addressed in real time. The ROM's output the non-standard 8 x 10 characters one row at a time, facilitating conversion into a high-speed serial video bit stream.

MOS does have its drawbacks --special handling techniques are necessary to prevent harmful buildup of static electrical charges. Special supply voltages that must be sequenced on and off are required. Interface circuits are necessary to convert from TTL to MOS voltage levels and vice versa. MOS is a relatively new technology and is better described as analog rather than digital. The ROM program must be specified at manufacture and cannot be altered. However, these disadvantages are far outweighed by the considerations leading to their selection listed above.

4.1.2 Character Structure and Position Requirements

Figure 4.1-2 "Character Structure and Spacing," graphically specified the character timing requirements. Each character is composed in an 8 x 10 dot matrix. (The squares in this matrix are turned "off" and "on" - dark or bright on a CRT face--to form a character). The 8 x 10 font size was selected after consideration of characteristics such as legibility and sharp definition.^{1,2} Other considerations include the number of characters required per line and the number of raster lines per display line.

The ROM has 8 parallel outputs, each output representing 1 column of a character. Each character column has a 70 nanosecond period, the minimum time interval encountered in the alphanumeric (A/N) circuitry. A continuous 14 MHz signal (70 nanosecond period) in sync with SPEC timing signals (sync, blanking, etc.) is used as the master clock for the A/N character generator.



CHARACTER STRUCTURE AND SPACING

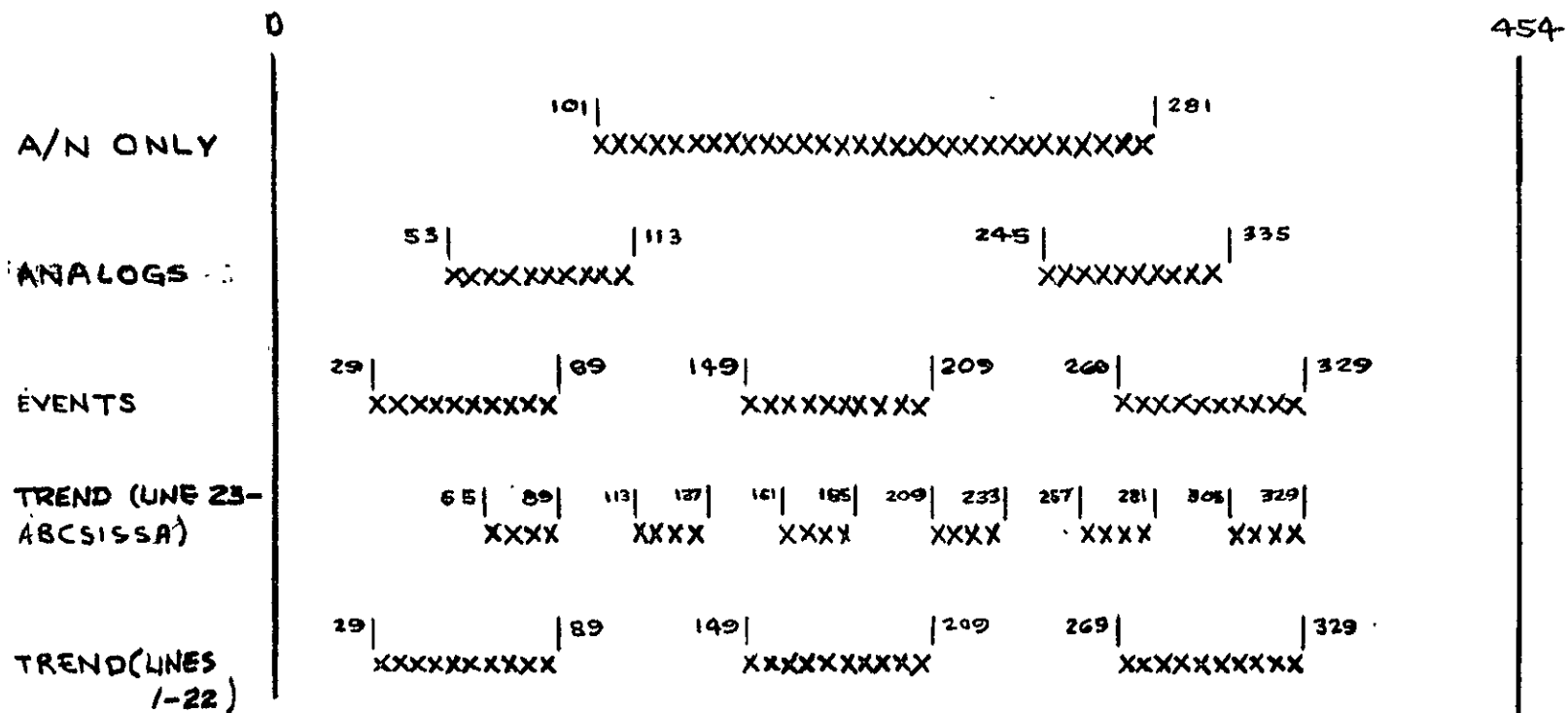
The characters are used to annotate the following types of displays in the formats described:

- Analog - write ten characters for measurement ID, stop (for the duration of the analog length), write fifteen characters depicting engineering units.
- Events - write ten characters for measurement ID, stop (for duration of event patch), repeat for the following two event patches.
- A/N Only - Write up to thirty characters in the middle of the CRT screen for titles and special notations. (Note: The number of characters is limited by the amount of logic utilized).
- Trend - same as Event format except for Line 23 which contains the abscissa scale. On Line 23 write six sets of four characters each according to the trend plot scale.

The character position requirements are illustrated pictorially in Figure 4.1-3.

4.1.3 ROM Timing

Figure 4.1-4, "ROM Clock Timing", illustrates the ROM clock waveforms and timing relationships. The clock period, "T", is determined by the width of an A/N character and the spacing between characters (refer back to Figure 4.1-2). The pulse width, "tpw", and spacing between clock phases, "td", were chosen to meet minimum clock pulse width requirements (150 nanoseconds minimum), spacing requirements (150 nanoseconds minimum), and for ease of generation from the 14 MHz clock.



X = ANY ROM CHARACTER, INCLUDING A "BLANK".

CHARACTER POSITION REQUIREMENTS

Figure 4.1-3

All A/N timing is derived from the SPEC master clock and timing logic. In addition to the externally generated, ϕ_1 and ϕ_3 clocks of Figure 4.1-4, the device generates two other clock waveforms internally. These are the ϕ_2 and ϕ_4 clocks. The four phase clock system is characteristic of MOS dynamic devices. This clocking system insures maximum speed, minimum internal loading and minimum internal power dissipation.

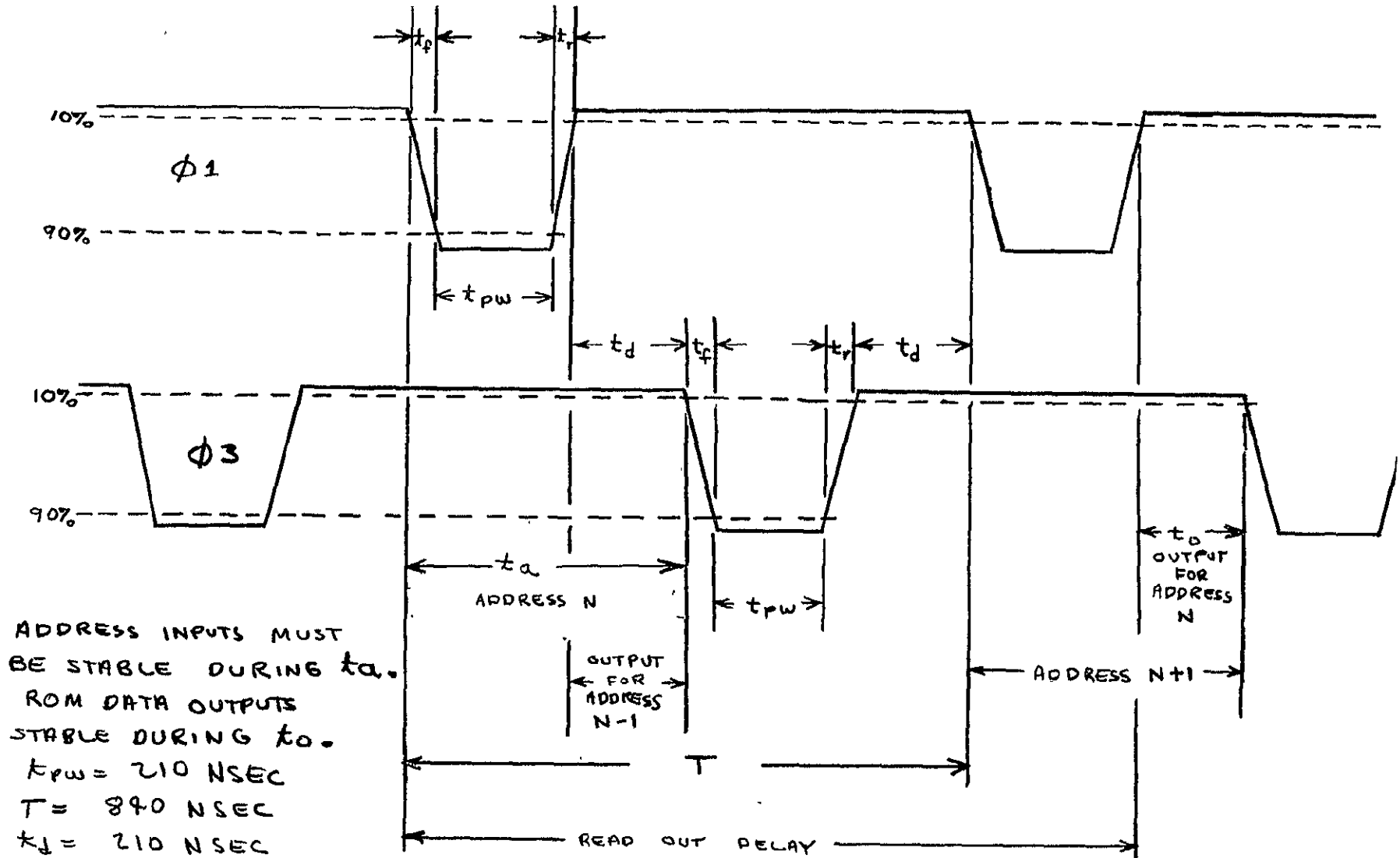
4.1.4 Character Addressing and Selection

A specific character, out of the 64 possibilities is selected when the six bit address code corresponding to that character is applied to the input gates of the ROMs. On any one display line (ten interlaced raster lines), up to 30 character written. If 30 characters are not required, the address code for a blank must be read in for all unused character locations. (For example, to annotate an analog, only 25 characters are normally needed. Therefore, the blank code is stored for the last 5 unused locations). The 30 character address codes (6 bits each) are loaded (2 codes at a time) into six 30-bit shift registers. These addresses are held here until needed.

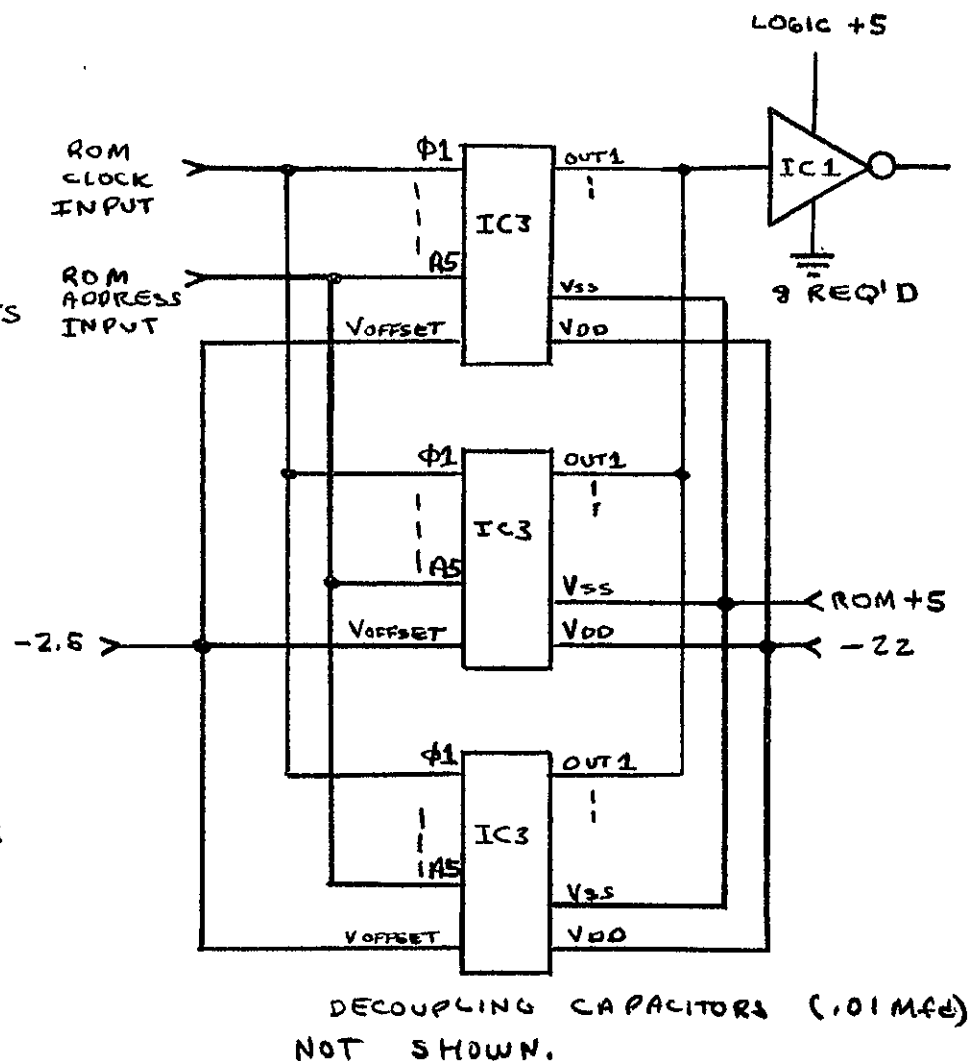
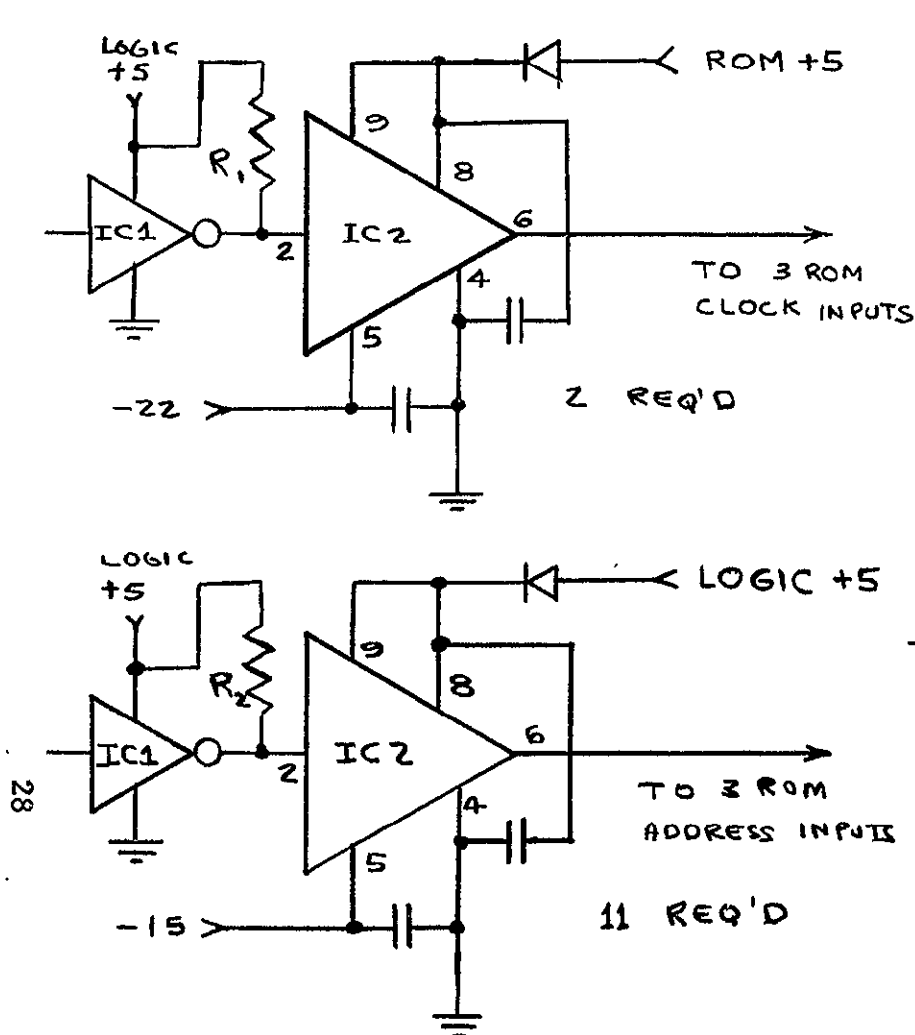
The address codes are recirculated within the 30 bit shift register or dumped out while new address codes are read in. The SPEC master clock controls the loading of the 30 bit shift registers.

The outputs of the 30 bit shift registers are clocked to the ROM interface circuits in parallel with memory select and memory clock lines. The memory select lines facilitate selection of the proper ROM as each ROM has a particular code that must be initiated before it will output. The memory clock lines control the memory decoding speed.

The output of the ROM's is in the form of 8 parallel outputs. Each output corresponds to a horizontal character bit as shown in Figure 4.1-2, "Character Structure and Spacing". The state of each bit (Logic "1" or Logic "0") is determined by the character address and by timing logic that defines which vertical line of the character is to be written. These 8 parallel outputs must be converted into a serial bit



ROM CLOCK TIMING



IC1 = TI SN74H04
 IC2 = GI NC611
 IC3 = GI MEM 2098
 ALL CAPS = .01 MFD
 $R_1 = 180\Omega$
 $R_2 = 220\Omega$

ROM +5 = 6.0 volts
 LOGIC +5 = 5.0 volts

DECOUPLING CAPACITORS (.01 MFD)
 NOT SHOWN.

MOS Logic "1" = -15 volts
 MOS Logic "0" = +5 volts

TTL/MOS/TTL INTERFACES

Figure 4.1-5

stream. A 9 bit synchronous parallel-to-serial converter which is composed of two 4 bit (MSI) Shift Registers (S/R) and a flip flop is used for this purpose. The resulting 9 bit shift register performs the conversion in the following manner:

- The first 8 bits of the 9 bit S/R are loaded in parallel with the ROM outputs. These ROM outputs are loaded synchronously by a single clock pulse.
- The correct output is then made to appear at the output of the ninth S/R bit by eight clock pulses following the load pulse.

Thus, the serial-to-parallel converter operates by synchronously loading in parallel and by synchronously shifting out in serial fashion.

4.1.5 MOS ROM Voltage and Interface Requirements

The MOS ROM's require different voltage levels and supply voltages from those used with TTL logic. Normally, the ROM's are referenced to ground and use three voltages, -5, -20 and -28. Translation circuits, using active devices, are necessary on both the inputs and outputs to interface with TTL.

The TTL-to-MOS interface and vice-versa is more easily accomplished by referencing the ROM's to +5 volts. Output devices, internal to the ROM's, are tied to -2.5 volts and drive one TTL gate input directly. The outputs of three ROM devices are connected to perform an "OR" function. Input level shifting is accomplished by using hybrid level shifters and driving the same inputs on each of the three ROM's in parallel. A simplified diagram of the ROM biasing and interface scheme is shown in Figure 4.1-5, "TTL/MOS/TTL interfaces."

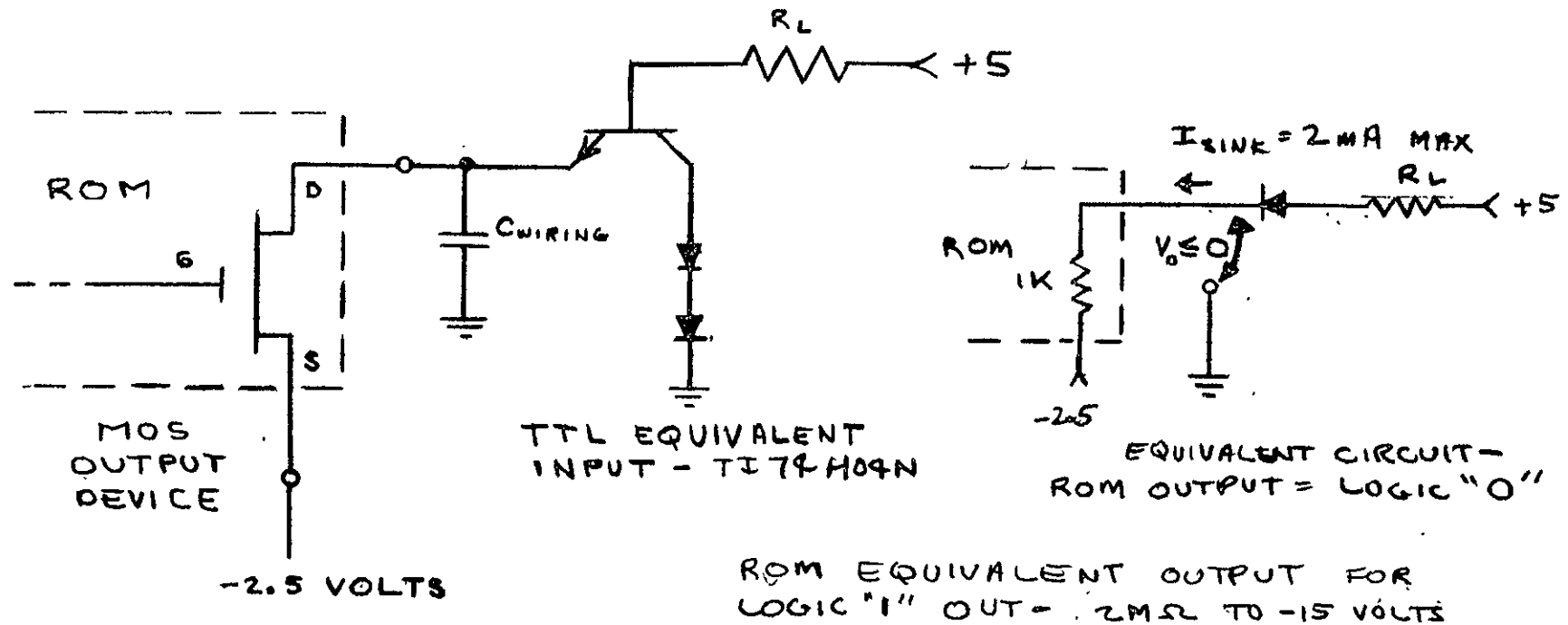
The General Instrument NC611, used as a TTL/MOS level shifter, is an AC device with high gain and is therefore susceptible to any voltage variation on the input. For this reason, a low value pull-up resistor is used on the output of the TTL buffer gates driving the NC611's. This pull-up resistor raises the logic "0" or "1" inputs are minimized.

The output MOS to TTL interface is accomplished by utilizing the output device internal to the ROM's. Figure 4.1-6, "Output Interface Analysis" illustrates the technique used in level shifting. Current sensing is used to obtain a high speed level conversion. The output device can either sink current (logic "0") or not sink current (logic "1"). The high output impedance of the device prevents fast voltage sensing (the RC time constant is such that poor rise times are inherent) but current sensing minimizing the switching times.

The ROM's have an electrical specification that no pin may be more positive than 0.3 volts with respect to the substrate. The substrate is normally held at +6 volts by the ROM power supply. If this supply should fail, or if it turns off faster or on slower than the logic +5 supply, the ROM's may be permanently damaged. The logic +5 voltage is used by the input level shifters and by the output buffer gates. The inputs and outputs of the ROM are subjected to positive voltages as long as the logic +5 voltage is connected to the ROM interface logic. Figure 4.1-7, "ROM Voltage Sequencer", shows the circuit used to sequence the logic +5 voltage into the interface logic after the ROM voltage comes up.

4.1.6 Physical Aspects of SPEC Alpha-Numeric Generation

Simultaneous presentation of two unique data pages, one on each color monitor, requires the use of two independent alpha-numeric systems. The two systems, although independent, possess identical capabilities. That is, each generator can produce any of six 6-four characters in an 8 x 10 format and position the characters as required by the current display.

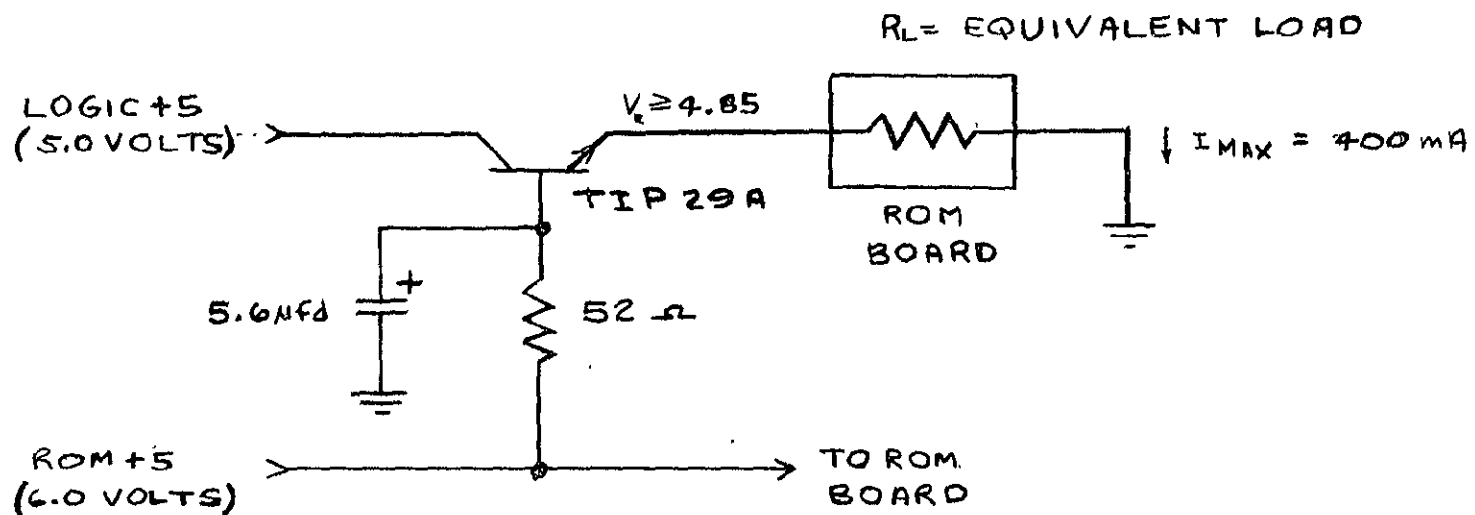


THIS INTERFACE UTILIZES CURRENT SINKING (RATHER THAN VOLTAGE LEVEL SENSING) TO CONVERT FROM MOS TO TTL LEVELS.

THE ROM CAN SINK CURRENT FROM THE TTL BUFFER GATE WHEN THE OUTPUT DEVICE IS TURNED "ON" AND CANNOT SINK CURRENT WHEN THE OUTPUT DEVICE IS "OFF".

OUTPUT INTERFACE ANALYSIS

Figure 4.1-6



TWISTED PAIR IS USED FOR ALL VOLTAGE ROUTING (NOT SHOWN).

ROM+5	6.0	5.0	4.0	3.0	2.0	1.0	0.0
V_E	4.9	4.2	3.5	2.7	1.8	0.9	0.0

TRANSFER CHARACTERISTIC

ROM VOLTAGE SEQUENCER

Figure 4.1-7

The combined space requirements for the two generators is five Augat hi-density DIP boards (each board accommodates 60 DIP's) and two double sided PC boards whose size is similar to that of the Augat boards. All boards are located in the Display Generation and Timing Enclosure.

Thus, generation of a well defined set of A/N characters has been achieved with a technique which is recommended for future TV data displays.

4.2 Color Data Displays

The use of color in information display is desirable primarily for the increased information capacity it provides. With three primary colors, 8 color combinations can be easily obtained. These are: black, red, green, blue, yellow, magenta, cyan, and white. In SPEC, both Analog and discrete data are displayed in color.

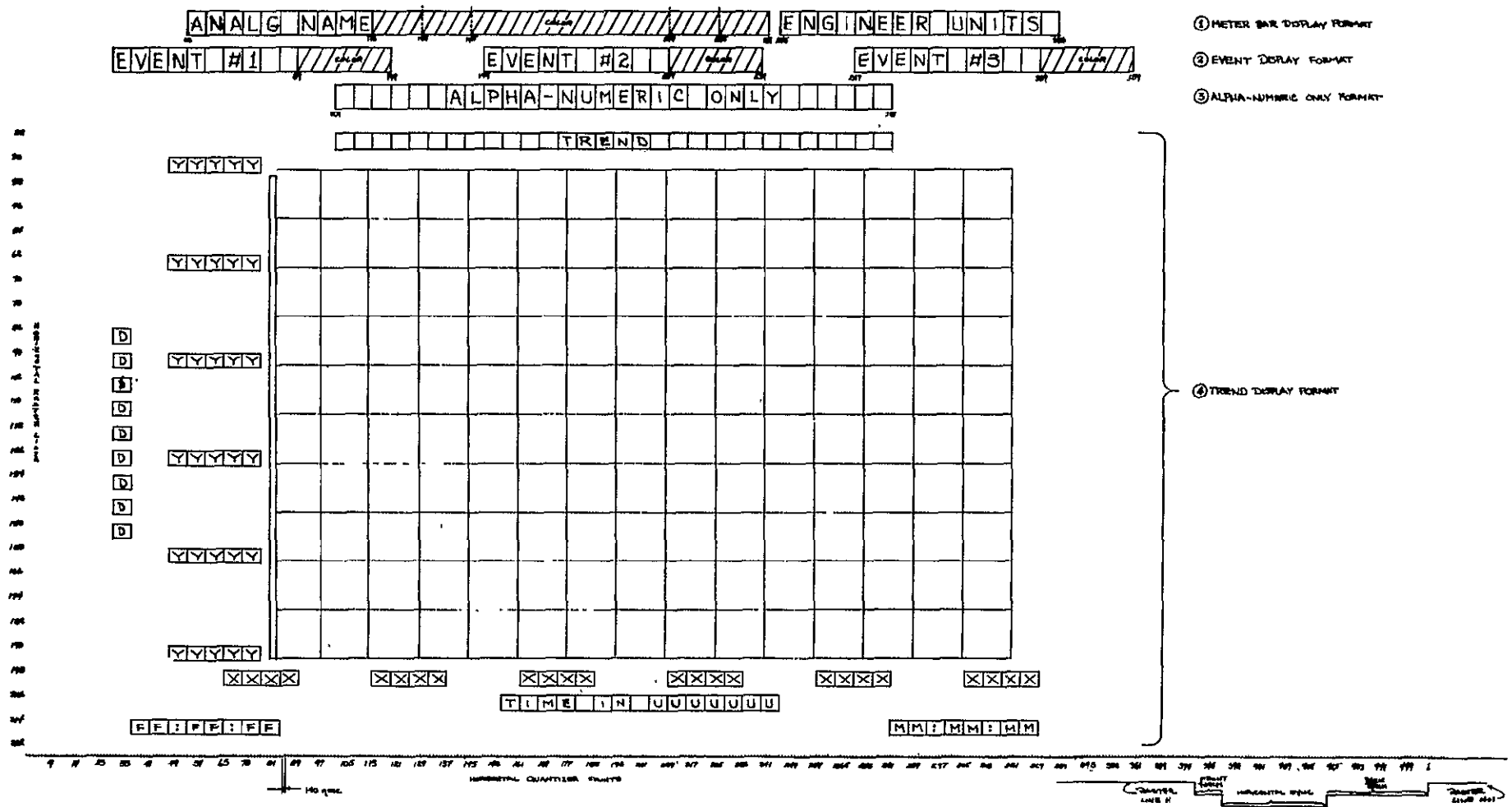
4.2.1 Analog Displays

The SPEC analog displays can be classified as (1) those measurement parameters with upper and lower limits and (2) those measurement parameters with the upper limits only, lower limits only or no limits.

The analogs with both upper and lower limits are displayed in a fixed format. That is, all analogs are linearly scaled to fit a hardware controlled format. Each analog occupies 10 horizontal raster lines/frame and up to 128 horizontal quantized segments of each raster line. In the fixed format, white reference lines are provided at 1/8 of full length as color changes from yellow to green, at 6/8 of full length where green changes to yellow and at 7/8 of full length where yellow changes to red. The red, yellow and green colors represent out of tolerance, marginal and intolerance respectively.

Up to 25 analogs/frame can be displayed. The first display line of Figure 4.2-1 (Meter bar display format), illustrates the analogs with fixed format. The white reference lines are represented by the vertical dashed lines.

Analog with upper limits only, lower limits only or no limits are displayed in a pre-determined format. In this mode the analog color and the point at which the color changes is under software control. The entire range of colors can be utilized if desired.



Display Presentation Timing

Figure 4.2-1

4.2.2 Discrete Displays

The discrete display consists of 75 event patches (3/row and 25 rows). For this type of measurement, color only has significance; length is meaningless. Consequently, the length of the event patches is fixed. In this display, as in the predetermined format for analogs, all 8 color combinations can be used if desired. Display Line 2 of Figure 4.2-1 illustrates the format for events with spacing for annotations. This figure is used only to illustrate the spacing and structure of the event patches and is not meant to infer all patches must be the same color. On the contrary, any patch can be any one of the 8 colors and is completely independent of the colors of the other patches.

4.2.3 Mixed Displays

Any combination of analog lines and event rows is possible in SPEC. This is, an analog bar can be displayed on any of the 25 display lines and can be preceded and/or followed by another analog or a row of event patches. In addition, provision is made to display up to 30 A/N characters on any of the 24 display lines. The attached photographs (Page 37) illustrate mixed displays of analogs of both types, discretized of different colors, and lines with A/N annotation only.

4.2.4 Color Monitors

The color presentations described in the previous paragraphs are all displayed on 17" Conrac color monitors, which employ shadow mask CRTs.

The shadow mask tube³ utilizes an electron gun for each phosphor and operates as indicated in Figure 4.2-2. The shadow mask is a thin perforated electrode which is placed close to the screen and is registered with it such that each hole in the mask coincides with a triad of three phosphor dots, one for each

PAGE 1 DISPLAY 1 09:31:07

RHU 2 DISCRETES

RHU 2 03A		RHU 2 03B		RHU 2 03C	
RHU 2 03D		RHU 2 03E		RHU 2 03F	

RHU 2 AC VOLTAGES

RHU 2 04		+121.1 VOLT RMS
RHU 2 05		+121.1 VOLT RMS
RHU 2 06		+3.22 VOLT RMS
RHU 2 12		+64.4 MV RMS
RHU 2 13		+0.644 VOLT RMS

RHU 2 VARIABLE RESISTANCES

RHU 2 16		+0.722 KILOHM
RHU 2 17		+1.205 KILOHM
RHU 2 23		+10.5 KILOHM
RHU 2 24		+15.0 KILOHM

PAGE 1 H DISPLAY 1

10:12:54

RHU 15 24

RHU 15 33

RHU 15 03H

RHU 2 03A

RHU 2 03D

RHU 15 04

RHU 15 03G

RHU 2 04

RHU 2 05

RHU 2 06

RHU 2 03B

RHU 2 13

RHU 15 03A

RHU 2 03B

RHU 2 03E

RHU 2 03H

RHU 2 03C

RHU 15 03G

RHU 15 03B

RHU 2 VARIABLE RESISTANCES

RHU 15 20

RHU 2 16

RHU 2 17

RHU 2 23

ALL RHU 15 EVENTS

RHU 15 03A

RHU 15 03D

RHU 15 03G

RHU 15 03B

RHU 15 03B

RHU 15 03H

+16.8 KILOHM

+0.775 VOLTS

RHU 15 03A

RHU 2 03C

RHU 2 03F

+124.4 VOLT RMS

RHU 15 03C

+124.4 VOLT RMS

+124.4 VOLT RMS

+3.88 VOLT RMS

+0.775 VOLT RMS

RHU 15 03C

+1.987 KILOHM

+0.824 KILOHM

+1.405 KILOHM

+11.4 KILOHM

RHU 15 03C

RHU 15 03F

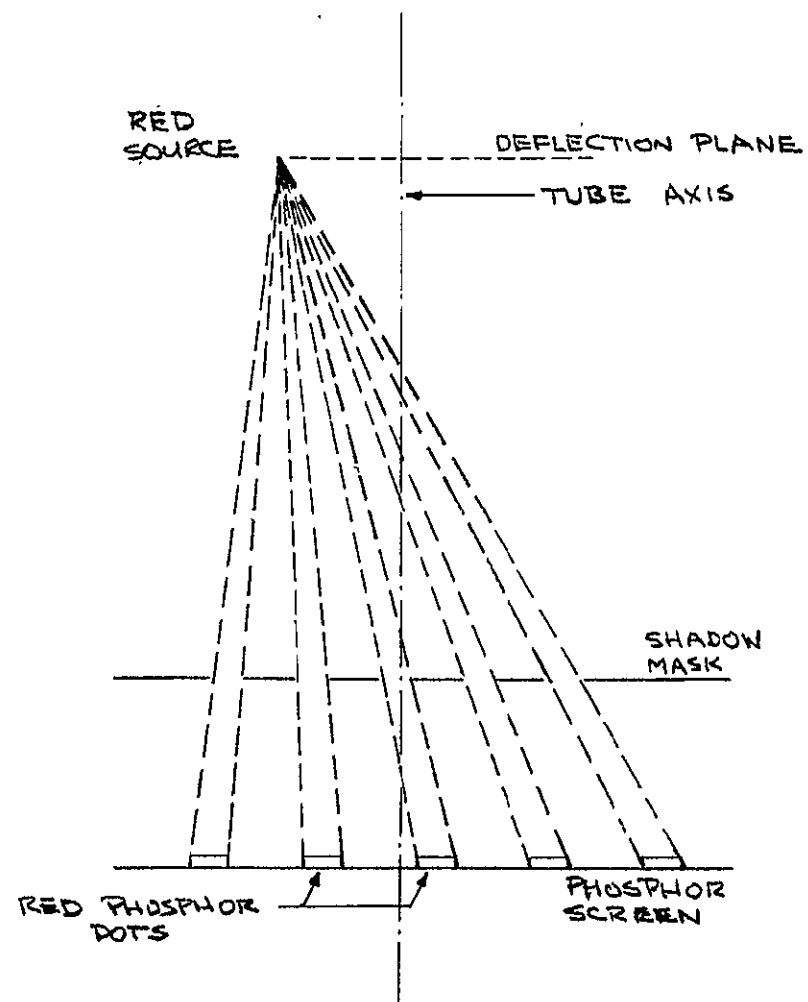
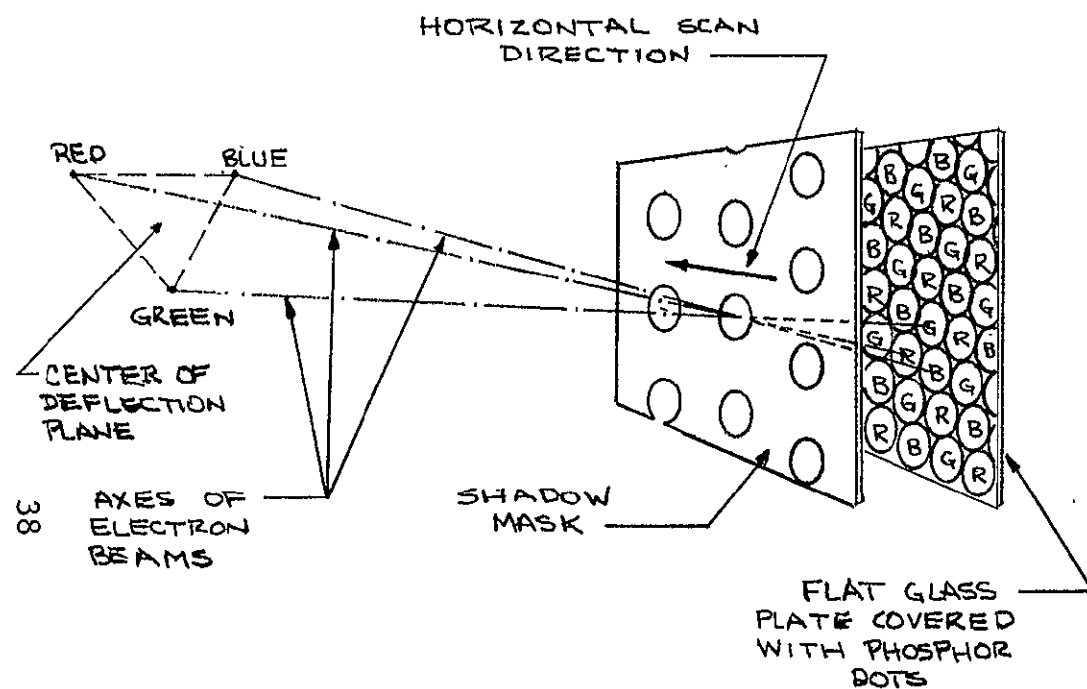


FIGURE 4.2.-2
SHADOW MASK COLOR TUBE.

primary color when properly adjusted, the gun alignment is such that only phosphor dots of one color can be energized by a given electron beam.

When a triad is excited by an electron beam, each dot of the triad emits a different color (red, green or blue). The characteristics of the human eye are such that the light emissions from a phosphor triad cannot be distinguished separately at normal viewing distances (two to three times the screen diagonal). The eye averages the three color emissions to give the appearance of a single color. For example, when the light outputs of a triad are equal, the eye sees them as a single white dot.^{4,5,6}

The dots of a triad are closely spaced but do not touch. Also only the areas of a dot falling under the path of the electron beam is illuminated. This results in a discrete, rather than a continuous, CRT image. That is, a picture is formed upon a color CRT face by individual non-touching dots of color, not by a series of continuously illuminated horizontal lines, as used in a monochrome CRT.

This discrete method of image generation results in a discontinuities in the optical response of a color CRT. In a monochrome CRT, the optical response falls off much as the frequency response of an amplifier. In a shadow mask color CRT, the optical response is linear (up to video inputs of about 2 to 3 Megahertz), then is dependent upon the phase relation of the high frequency video inputs and phosphor dot spacing. The optical response becomes erratic and unpredictable as the video information becomes denser than the number of dots per raster line.

While use of a shadow mask CRT for colored information display leaves room for improvement, particularly in character legibility and maintenance of alignment, the results obtained are satisfactory. Use of color TV for checkout data display is particularly significant in light of future anticipated improvements in conjunction with the established advantages of display flexibility, compactness, and increased information content.

4.3 Trend and Graphics

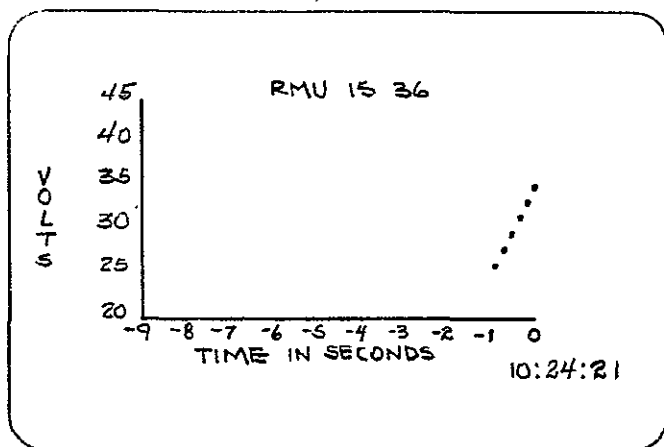
Time varying data can be plotted several different ways. Data can be plotted over a specific time interval at the end of which the display remains static or the display can be erased and the next time interval plotted. Another alternative is to make the display continuous wherein the plot is much like that of a strip chart recorder. In SPEC, real time data or historical data can be plotted in these formats on a variable time base grid with the appropriate annotations along both ordinate and abscissa. Figures 4.3-1, 4.3-2 and 4.3-3 are pictorial sequences which illustrate the different types of trend curve presentation.

In addition to these methods of presenting time varying data, a parameter can be plotted as a function of an independent variable other than time. In this mode of operation (graphics), pictorial information can also be presented by applying the proper X and Y axis drive signals.

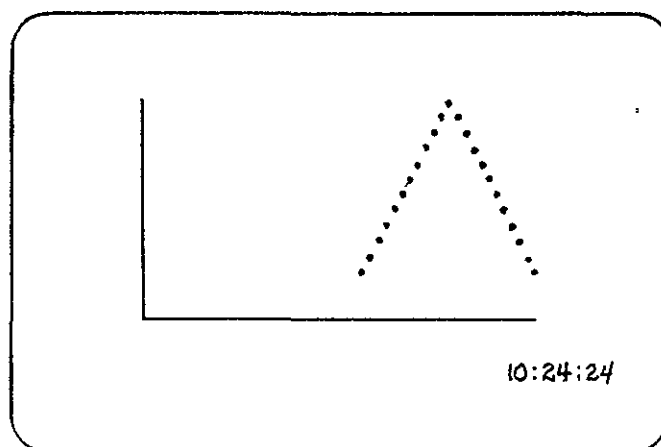
4.3.1 Plot Generation

A scan converter is used to generate the trend plots. Figure 4.3-4 illustrates the operation. This device typically consists of two CRTs placed face to face. One tube is operated in an oscilloscope type mode as a write tube. The read tube scans the display on the write tube and outputs a video replica. The SPEC scan converter is somewhat unique in that only one tube is used with a single beam serving both read and write functions. The beam scans the tube face in the standard 525 line/frame format. Reading occurs as the beam sweeps across the CRT. Writing is achieved, point by point, during the horizontal retrace interval. A portion of Figure 4.3-4 represents a typical segment of the CRT. The solid lines are representative of the read cycle while the dotted lines illustrate the point by point writing during retrace. The Scan converter can be operated in several modes which are selectable under software control. These are:

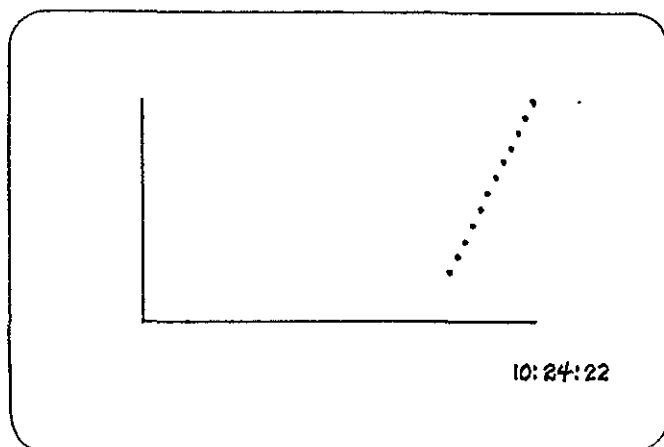
INPUT
WAVEFORM



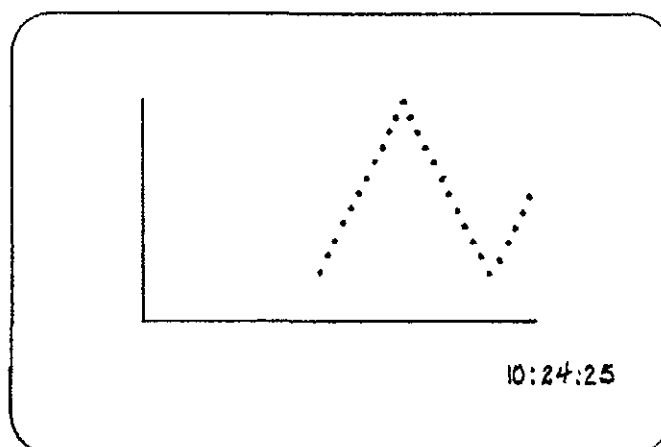
(1)



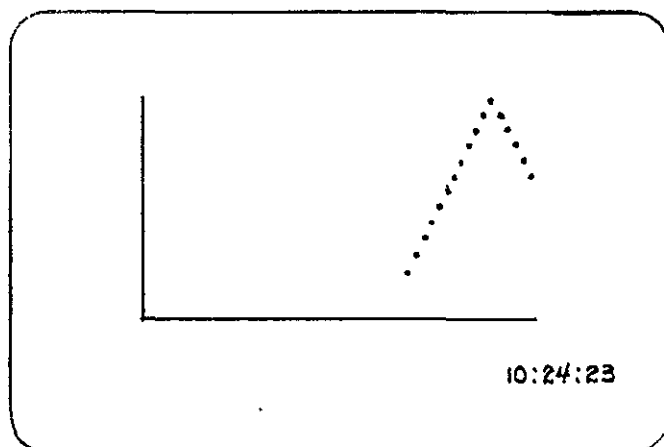
(4)



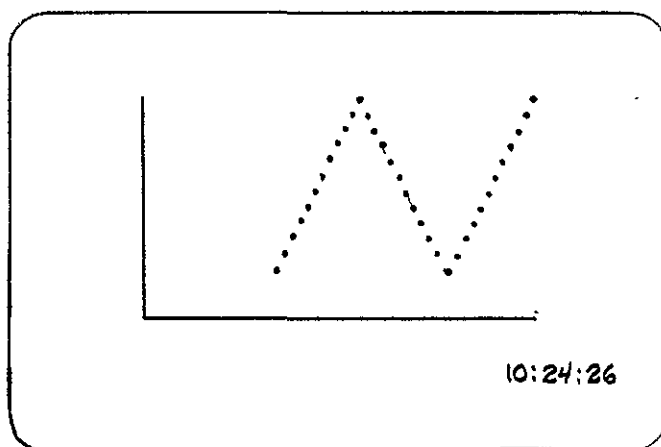
(2)



(5)



(3)



(6)

FIGURE 4.3-1.
HYPOTHETICAL MOVING WINDOW PLOT
41

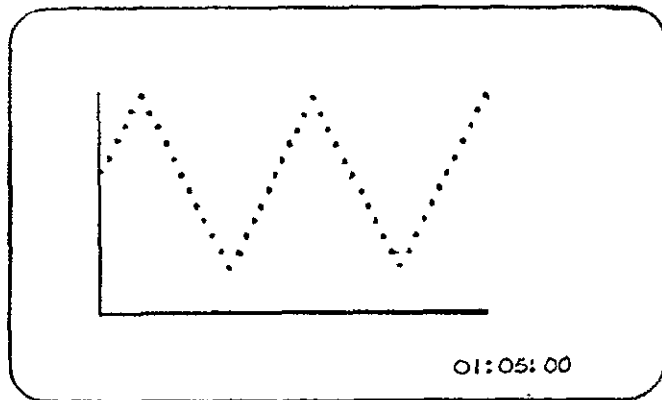
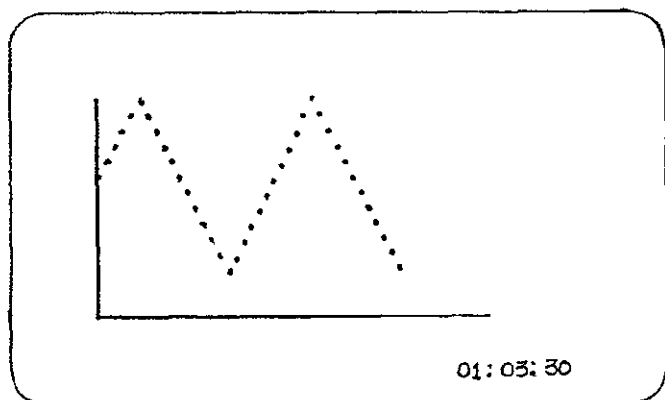
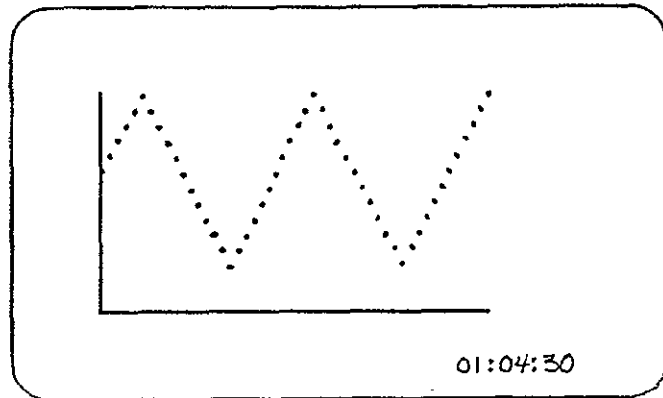
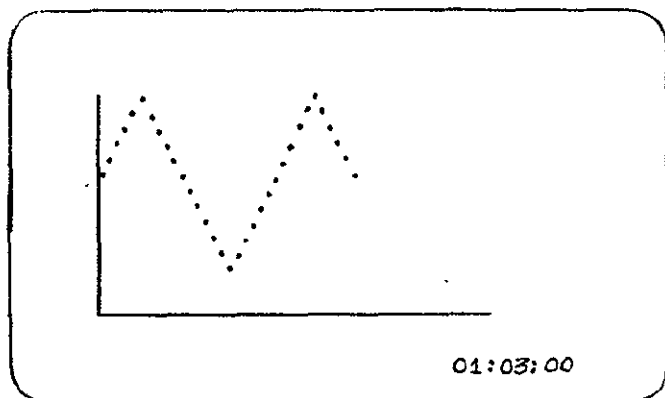
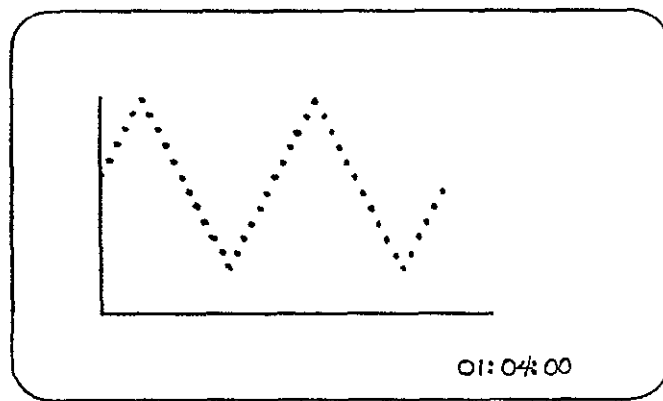
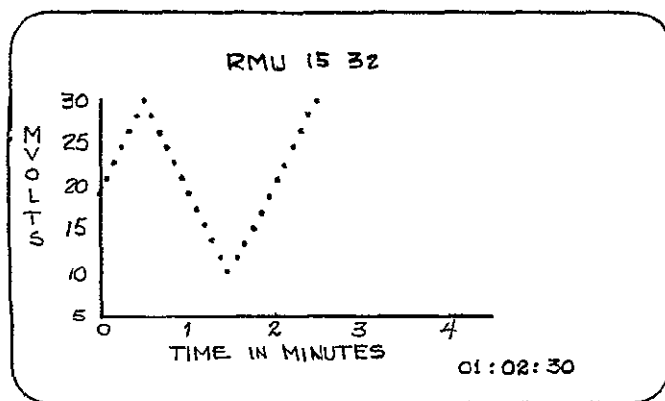


FIGURE 4.3-2
HYPOTHETICAL STATIC PLOT

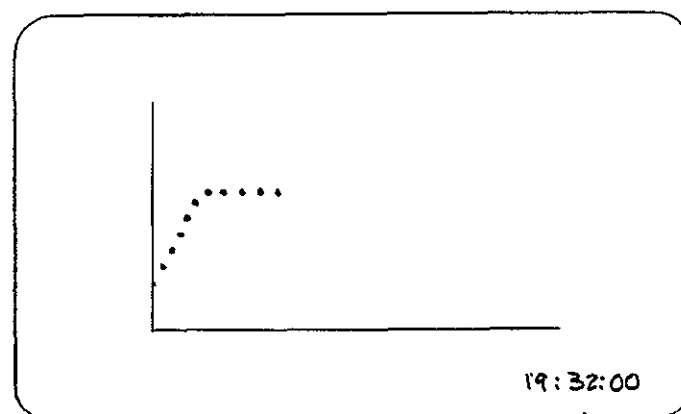
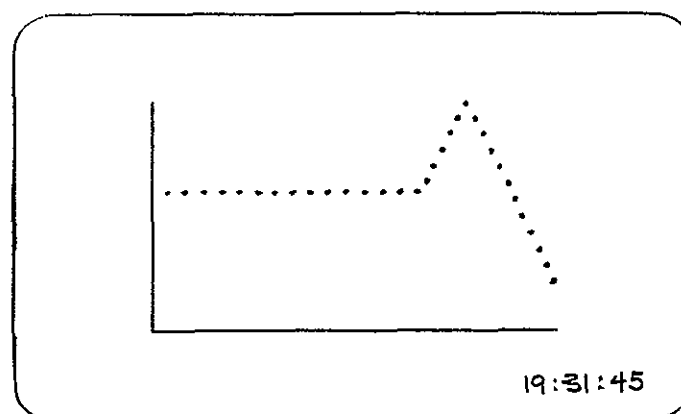
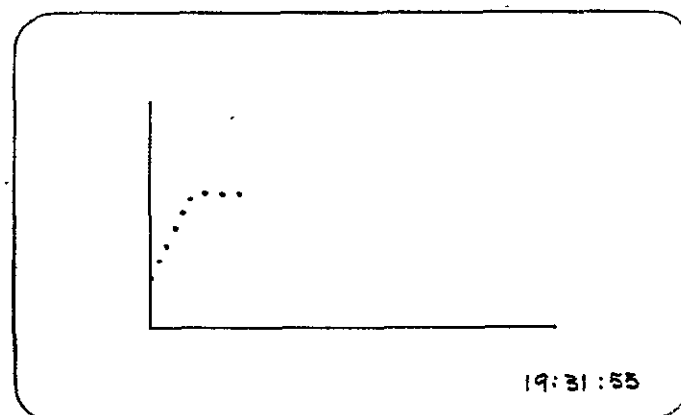
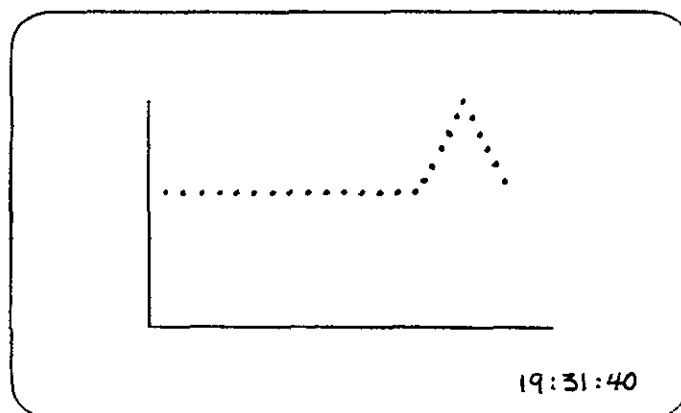
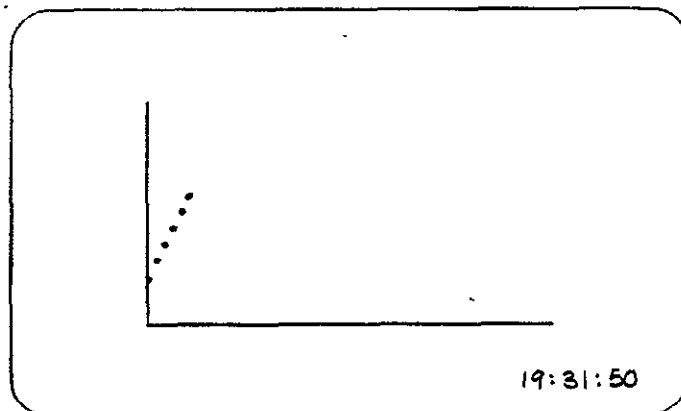
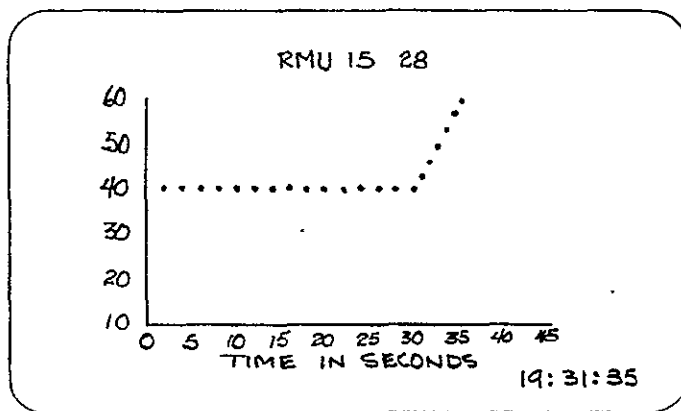
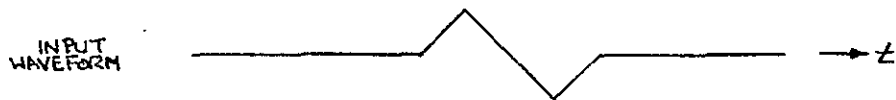


FIGURE 4.3-3.
HYPOTHETICAL REPEAT PLOT

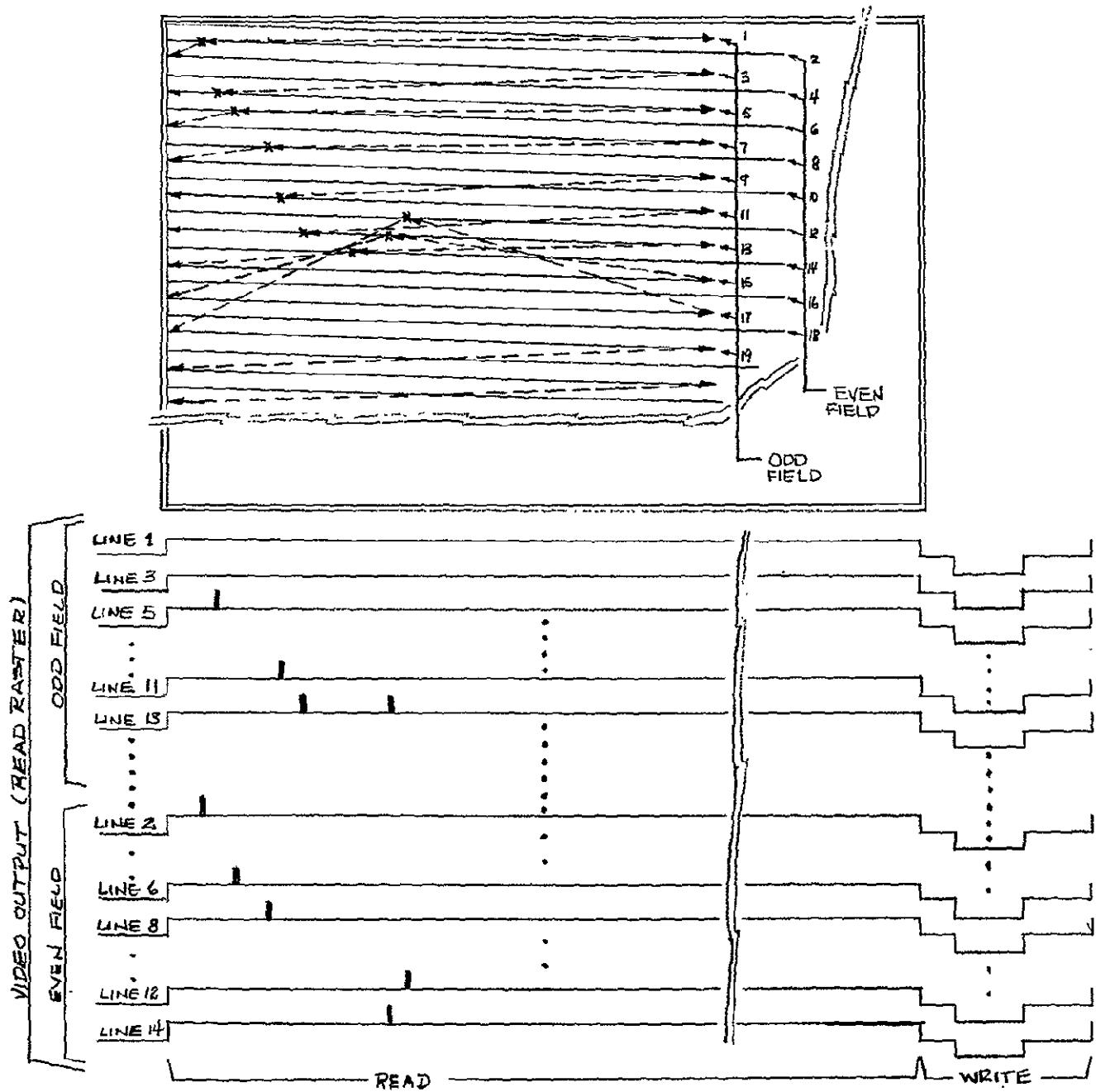


FIGURE 4.3-4

- Background - Black on white or white on black
- Store/non-store
- Erase - generates a 200 milli-second erase pulse for the scan converter.
- Integrate - used to display a fast changing low repetition rate pulse.
- Read only and write only modes.
- Read/Write - selected when read only and write only are not selected.
- Scale factor - 1x, 2x, 4x, and 8x. In the 1x mode it takes 300 individual x coordinates to write a line across the face of the CRT. In the 2x mode it takes 600, 4x - 1200, and 8x - 2400.

The scan converter receives data for the plots from interfacing circuitry. This circuitry serves as a communication link between a computer I/O module and the scan converter. It buffers the trend information stored in memory on its way to be written on the face of the CRT in the scan converter. The data leaves the memory and goes through the interface where it defines X and Y coordinates. In the time varying, or sweep mode, the writing beam is deflected linearly in the X direction as a function of the selected time scale. In the graphics mode, the X coordinate is independent of time. In either mode, the coordinates are changed to an analog voltage and fed directly to the deflection coils of the scan converter CRT to be written as a point per horizontal sweep during retrace time. The CRT is raster-scanned to develop a video signal which in turn is fed to a monitor. The final destination of the trend information is then a graph on the face of the monitor.

4.3.2 Annotation and Grid Generation

The trend grid consists of a series of vertical and horizontal reference lines as shown by the trend display format of Figure 4.2-1. The grid is fixed and will appear as shown whenever a trend plot is called. The grid annotations are supplied by the A/N generator and can be changed by an appropriate keyboard entry. The ordinate and abscissa scales are variable and are also under keyboard control.

4.3.3 Video Mixing

The trend plot output from the scan converter is a composite video signal (the signal contains video information with sync and blanking). The trend grid and annotation signal is video without sync and blanking and is therefore non-composite. In order to obtain a single trend signal which is composite video, the trend plot output and the trend grid and annotations are video mixed. The video mixer is an integral part of the scan converter and therefore, an additional external mixer is not required. Since the scan converter is operated in sync with the timing signals from which the grid and A/N are derived, the resulting mix is a single composite video signal. The scan converter video system does not provide for color insertion and therefore the resulting display is black and white. Multi-colored trend displays are possible, however, with appropriate encoding of the trend plot video signal.

4.4 Test Control

Operator control of a test is achieved in SPEC through use of a control display and a keyboard. Implementation of the SPEC test control function involves three areas of particular significance to future checkout applications. First, in order to provide more efficient man/machine communication, interactive control was developed. Secondly, use of a variable function keyboard provides an almost infinite number of uniquely named switches for use by the operator in entering information. And thirdly, the manner which is used to input information to the computer provides for simultaneous verification that the keyboard entry was correct and that the computer received the correct entry.

The Control hardware consists of a modified Uniscope 300 and special interfacing circuitry as shown in Figure 4.4-1. The Uniscope 300 modification consists of physically and functionally separating the display and the keyboard. The interface circuitry serves as the communication link between the SPEC processor and the modified Uniscope 300.

4.4.1 Control Display

A caligraphic, or stroke writing, type of cathode ray tube (CRT) display is used where the viewing surface is 10 inches wide and 5 inches high. A total of 1024 characters can be written on the screen in a format of 64 stroke characters on each of 16 lines. Each character is .150 x .113 inches. The character brightness may be varied from 70% brightness to full brightness. The attached photograph (NASA S-70-36541) shows a typical control display presentation.

The left hand portion of the top line (line 0) is used for the primary operator instruction. One of two messages will be displayed in this field. The question "SELECT?" indicates that the SPEC program is ready to receive a function command from

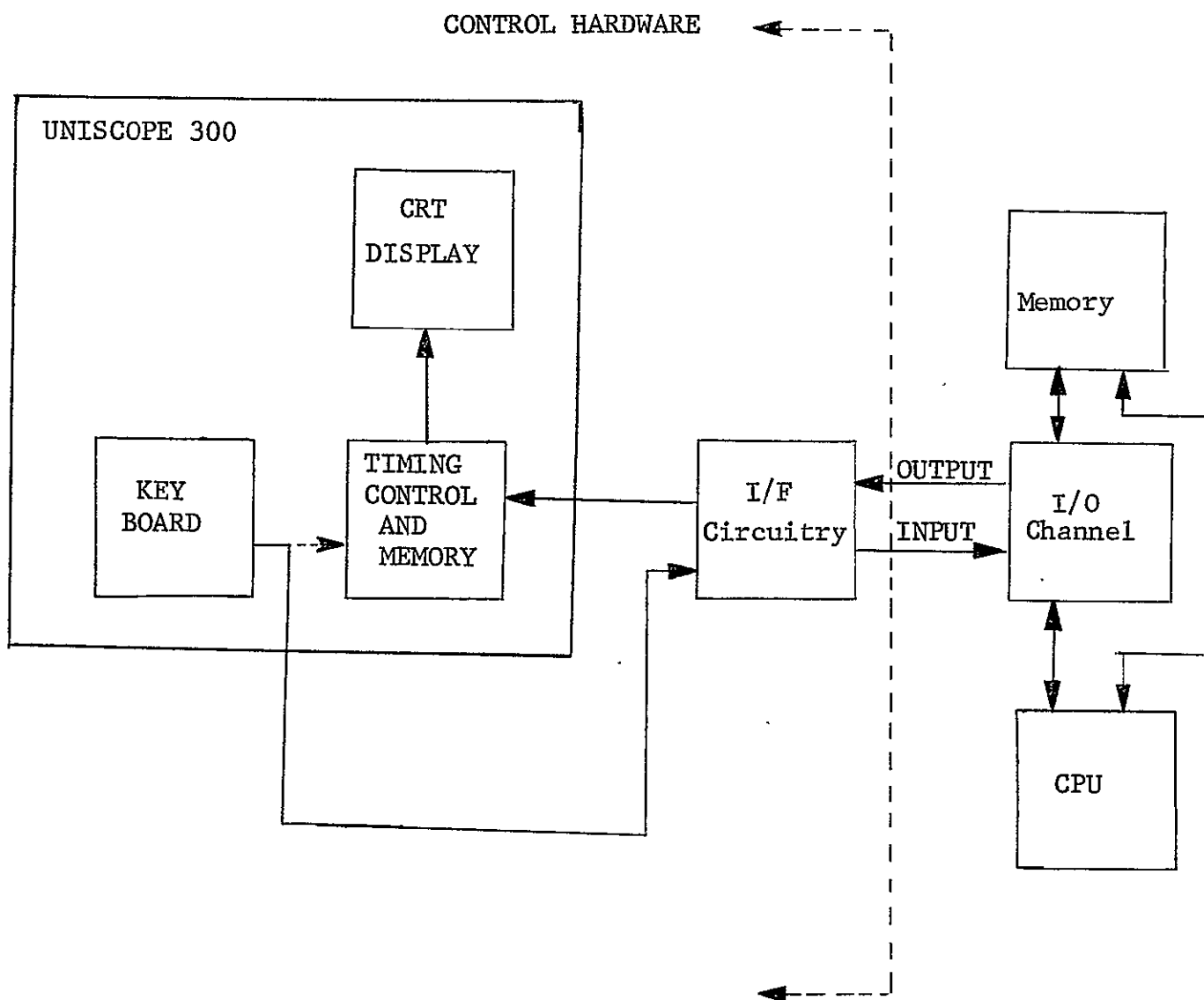


FIGURE 4.4-1

ANS LN 2

PAGE IM SAVED

TIME 10:37:07

1 ☐ ACTIVE

PLOT RMU1536 Y LIMITS = 22 TO 36

2 ☒

*INHIBIT PROCESSING ON DISPLAY 7

3

4

5

6

7

8

9 LOC 012345 04221 00524 10301 11340 02200 12236 04211 00503

10

11

12

13

14

15

OPS SYS PROGRAM READY

the operator. The display "ANS LNX" (Answer Line X, where X = 1 to 8) indicates that a previously selected function requires additional information or direction, and that a question appears on Line X. The next field, or portion, of the top line is used to display errors pertinent to the primary operation instruction. These errors include "ILLEGAL FUNCTION" if a non-allocated function key has been entered and "ILLEGAL OVERLAY" if the keyboard overlay in use does not correspond with the program which is loaded. The remaining character field in Line 0 is used for console status information including saved page indication, loss of sync (LOS), and real time.

Lines 1 through 8 are used for tutorial displays. Each time a function is called in response to the primary operator instruction "SELECT?" the first available line is assigned to the called routine. The left most field in each of these lines is used for line number. This is followed by a display of the key character from the function key which initiated the action. The next field is used for command status such as:

-COMPLETE	meaning action completed.
-ACTIVE	meaning function in progress, line cannot be used until complete.
-CANCELLED	meaning action cancelled by operator.
-INPUT ERR	response to question in error

The remaining field (character Number 16 through 64) is used for tutorial displays as required.

Lines 9 through 15 are available for general display purposes. In the photograph, the contents in octal, of selected memory locations are being displayed. Line 15 is being used to denote which program is loaded and its status.

Operationally, the control display and the keyboard in conjunction with the required software provide a conversational mode of communication between the console and the operator.

4.4.2 Keyboard

The keyboard contains two types of keys. On the right are seven columns of five keys each. These are referred to as variable function keys. The remaining keys are fixed function and include the standard alpha-numeric keys, five special character keys, and several control keys.

The variable function key capability is provided through use of plastic overlays containing the desired key designations. As indicated in Figure 4.4-2, the overlay is constructed with a certain combination of tabs present. When the overlay is in place on the keyboard, the tab combination is detected by microswitches which cause a seven-bit code to be transmitted to the computer each time an entry is executed. This code, used in conjunction with the function key code, expands the use of the variable function keyboard to over 4000 unique switches and allows interlock to assure that the correct overlay is in use with any program and/or parameter load. If desired, the overlay can be used to call, or load, a new program.

In general, the variable function keys are used to designate certain generic actions such as page call up, or initiate test stimuli (i.e., valve operation, relay closure, program load). The alpha-numeric keys will then be used to specify which member of the genus is requested (i.e. page number or valve designation). The transmit (execute) key is used to execute the information input by the operator.

This keyboard approach permits the switches that are used for checkout stimulation and control to be designated identically with controls that are integral to the system under test.

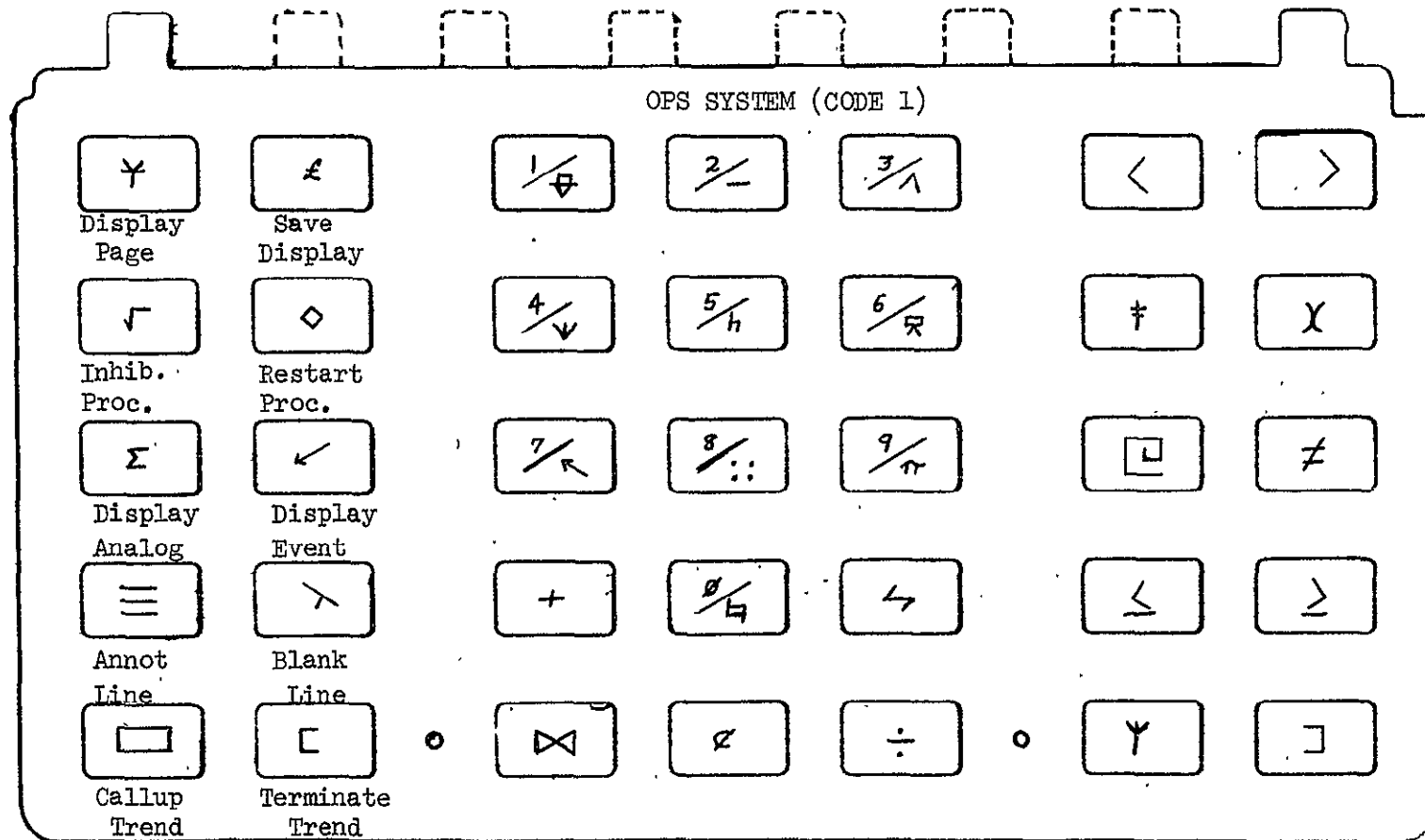


Figure 4.4-2.

4.4.3 Information Entry Verification

In a conventional remote terminal operation, a message is composed, entered in the display memory, verified correct on the display, and then it is caused to be transmitted to the computer for action. In this operation, a transmission error can occur and be undetected possibly causing an improper computer action unless an additional verification step, redundant transmission, or other means is used.

In SPEC, this difficulty is overcome by transmitting directly to the computer the character representing each key as it is depressed. The computer in turn transmits the respective characters back to the control display. As the operator then verifies that he has correctly entered and composed his message, he is also verifying that the computer has correctly received his message. Execution of the action, at this point, is strictly a computer (and possibly output device) operation, since errors in information entry have been eliminated.

In order to obtain this type of operation with the Uniscope 300, it was necessary to modify the unit, as indicated in Figure 4.4-1, by disconnecting the normal keyboard to display memory connection and by interfacing the keyboard directly to the computer through an I/O channel. Since the Uniscope receives data in serial form, additional error detecting capability is provided for the computer output transmission by use of message parity.

Early evaluation indicates that while improvements can be expected, this approach to test control will provide the operator with a highly efficient and flexible means of maintaining communication with the checkout system.

5.0 CONCLUSION AND RECOMMENDATIONS

The SPEC feasibility model was developed to achieve four primary design objectives. The degree of success in fulfilling these objectives, possible applications of the console and recommendations are included below.

5.1 Conclusion

The design objectives of the SPEC Contract were to develop an engineering feasibility model which would:

- Accept and present available test data to a spacecraft systems test engineer as a highly concise, decision-oriented display.
- Provide greater operator flexibility in data selection and display than previously available.
- Eliminate time-consuming hardware patching, of data lines necessary to configure displays, prior to spacecraft testing.
- Provide a data entry device for evaluation which could lead to a single standard data entry device for operation communication with the central computer.

These design objectives have been successfully implemented and were demonstrated during acceptance testing.

The techniques developed in SPEC are primarily man-machine oriented and lend themselves directly to several applications. Applications include upgrading the current Acceptance Checkout Equipment-Spacecraft (ACE-S/C Control Rooms, and development of a Universal Test Console (UTC) to be used in checkout and test of future space hardware. Also included is any operation involving large amounts of data, rapid operator decision and

reaction, and display and control flexibility. Operations such as process control, mission control or medical monitoring are prime examples.

5.3 Recommendations

The SPEC embodies the design efforts and results of studies initiated to achieve the original design objectives in an optimum configuration. During the months of design, fabrication, and checkout, several areas of improvement were recognized which could enhance the features of SPEC and future consoles. These improvements are briefly described as follows for future consideration:

(a) As in any breadboard development, there are a number of improvements (particularly in the logic design) which could be incorporated to optimize the design. These include greater use of MSI to reduce volume, analysis of each logic function and its associated packaging to remove any marginal condition which may become apparent with time, and minimization of the logic required. It is recommended that this action be taken prior to using this circuitry for new design or production.

(b) It is recommended that additional investigation and development be performed to improve the performance of the trend display particularly with regard to reduced flicker with black background, fast transient plotting capability, and simplifying the method of changing a plot format.

(c) To improve the operator's capability for detecting key errors and to reduce operator fatigue, it is recommended that the control display CRT be lowered and that the keyboard be moved further inward on the work surface. This will reduce the amount of eye movement required to verify entries and will also provide arm support. Associated with this area of the console, it is recommended that the slide selector switch be lowered to a position more accessible to the operator from a sitting position, and that the seven power supply indicator lamps be moved from the front panel to an internal location and that a summary console FAULT indicator be installed near the console ON/OFF switch.

(d) It is recommended that several of the keyboard function key labels be changed to better serve the SPEC application. As an example, these include changing CURSOR TO HOME to CANCEL; TRANSMIT to EXECUTE; and interchanging the functions of the CHAR ERASE key and the space bar.

In addition to these recommendations that relate to SPEC in its present configuration, the development of a true stand-alone console, which physically contains the required processor and memory functions, is urgently needed to realistically establish the total capability versus size and cost aspect.

Other areas where continued development is recommended include color CRT displays, function keyboard, simultaneous multiple parameter trend plots, film data utilization, hard copy techniques, and a modular console design.

The success of this project was due to the combined effort of many individuals, including both NASA and G.E. personnel. The particular contributions of F. L. Boyd, J. K. Bergen, and H. C. Juel to the writing of this report are recognized and acknowledged.

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