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ABSTRACT

This report describes the remote computer terminal designed for student use in the PLATO IV computer-assisted instruction system. The terminal features a plasma display panel, self-contained character and line generators, and the ability to communicate over voice grade telephone circuits. Operating modes and control characters are described in detail. A summary of terminal generated data and its output format is also included. (CH)

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THE PLATO IV STUDENT TERMINAL

JACK STIFLE

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THE PLATO IV STUDENT TERMINAL*[1]

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ABSTRACT

This report describes a graphics terminal designed for use as a remote computer input-output terminal. The terminal features a plasma display panel, self-contained character and line generators and the ability to communicate over voice grade telephone circuits.

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*This work was supported in part by the Joint Services Electronics Program (U.S. Army, U.S. Navy, and U.S. Air Force) under Contract DAAB-07-67-C-0199.

[1]This report was originally titled, "A Plasma Display Terminal," when published in March, 1970 and March, 1971.

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CHAPTER 1 - DESCRIPTION

1.0 Introduction

This report describes the student terminal (remote computer terminal), designed for use in the PLATO IV computer-aided-instruction (CAI) system. Although the terminal is intended for use in teaching applications, it has many features which make it useful in many other computer terminal applications. These features include:

1. An 8 1/2-inch square plasma display panel that is readable in a brightly lighted room without eyestrain.
2. Permanent storage of information on the display screen without flicker. Absolutely no refreshing of the display panel by the computer is required.
3. Self-contained character and line generators.
4. A character writing speed of 180 characters per second and the capability of displaying up to 2048 characters on the screen.
5. A line drawing speed of 60 lines per second.
6. A character repertoire of 256 characters, 128 of which are alterable via the computer program.
7. The ability to transmit and receive data on voice grade telephone circuits.
8. A random-access slide projector for rear projection of static information on the display screen.
9. Additional input-output channels for the control of auxiliary equipment.
10. An optional random-access audio response unit.

There are three general requirements which may be used to characterize a CAI computer terminal.

First, the terminal must be capable of serving the needs of a broad

class of relatively unsophisticated users, most of whom will be encountering computer terminals for the first time. Users might include, for example, grade school students studying arithmetic or geography, high school students studying French or Spanish, and college students studying biology or chemistry. The terminal must present information to each of these users in a form that he can readily understand.

Second, the terminal must be capable of remote operation via low grade telephone lines. This requirement is essential to permit the locating of terminals in widely separate schools without the need for expensive communication links.

Third, the terminal should cost less than $5000 to be competitive with the present costs of education.[1]

To meet the first requirement mentioned above, the terminal must have graphical capability. It must be able to present pictoral information such as maps, graphs, circuit diagrams, anatomical drawings, etc. Some type of line generator which can be used to generate such objects is thus required.

A very versatile character generator is also required. The terminal must be capable of displaying not only upper and lower case English alphanumeric characters, but also foreign language characters and any special symbols which may be unique to a particular subject under study. Such a need implies a character generator whose repertoire can be dynamically altered by the computer.

The need for operation over low grade telephone lines implies a limited

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[1] D. Alpert and D. Bitzer, "Advances in Computer-based Education," Science, March 20, 1970, Volume 167, pp. 1582-1590.

available bandwidth of approximately 1200 bits/second. Such low bandwidth necessitates local storage of information within the terminal.

Depending upon the data format used, anywhere from 75K to 250K bits of memory may be required to store immages for presentation on a cathode-ray tube (CRT) with 500 line resolution. A relatively high bandwidth, typically 4.5 MHz, is required between this memory and the CRT to prevent flicker of the image. Fast digital to analog (DA) converters may be required to interface the terminal processing unit to the CRT.

Direct viewing storage tubes may be used to overcome the flicker problem but these devices suffer from low brightness and the inability to perform selective erase operations on the displayed data.

The use of a plasma panel,[2] on the other hand, with its inherent memory, eliminates the refresh memory while preserving the selective erase function. Because each point is stored on the panel as it is displayed, the terminal electronics need operate only fast enough to stay ahead of the incoming data. A panel writing rate of 30 KHz is adequate for this application. The digital nature of the plasma panel also eliminates the need for any DA converters.

The thin transparent structure of the plasma panel permits the panel to be used as a screen for the viewing of information in the form of slides or microfiche which can be projected on the rear of the panel. Such informa-

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[2] R. L. Johnson, D. L. Bitzer, and H. G. Slottow, "The Device Characteristics of the Plasma Display Element," IEEE Transactions on Electron Devices, Vol. ED-18, No. 9, September 1971, pp. 642-649.

tion can be stored in the terminal and projected on the panel, under computer control, thus providing a presentation of dynamic computer generated data superimposed on static (slide) data. This local storage of static information reduces the memory required in the central computer and at the same time results in more efficient use of the communication link.

1.1 Terminal Description

A block diagram of the prototype terminal is shown in Figure 1.0. The serial input port is designed to accept data arriving at a rate of 1200 bits/second in the form of a frequency-modulated (fm) signal, which permits the terminal to operate on voice grade telephone circuits. The terminal word size is 20 bits and therefore the terminal word rate is 60 words per second. The terminal word format is discussed in Chapter 2.

The demodulator recovers the data from the fm signal and shifts the data into the serial input register (SIR). After a full word has been assembled in the SIR it is transferred to the Data (D) Register.

The 20-bit D register is the distribution center of the terminal. From this register data may be transferred to all internal sections of the terminal as well as any external equipment connected to the terminal.

The 5 bit mode register (M) is analogous to the instruction register in a digital computer. This register directs the Terminal Control section in the processing of incoming data. Terminal Control provides the timing and control signals for controlling the flow of data within the terminal. Four modes of operation are available and are discussed in Chapter 2.

The data is displayed on a Digivue* Plasma Display Panel. This panel

*Trademark of Owens-Illinois, Inc.

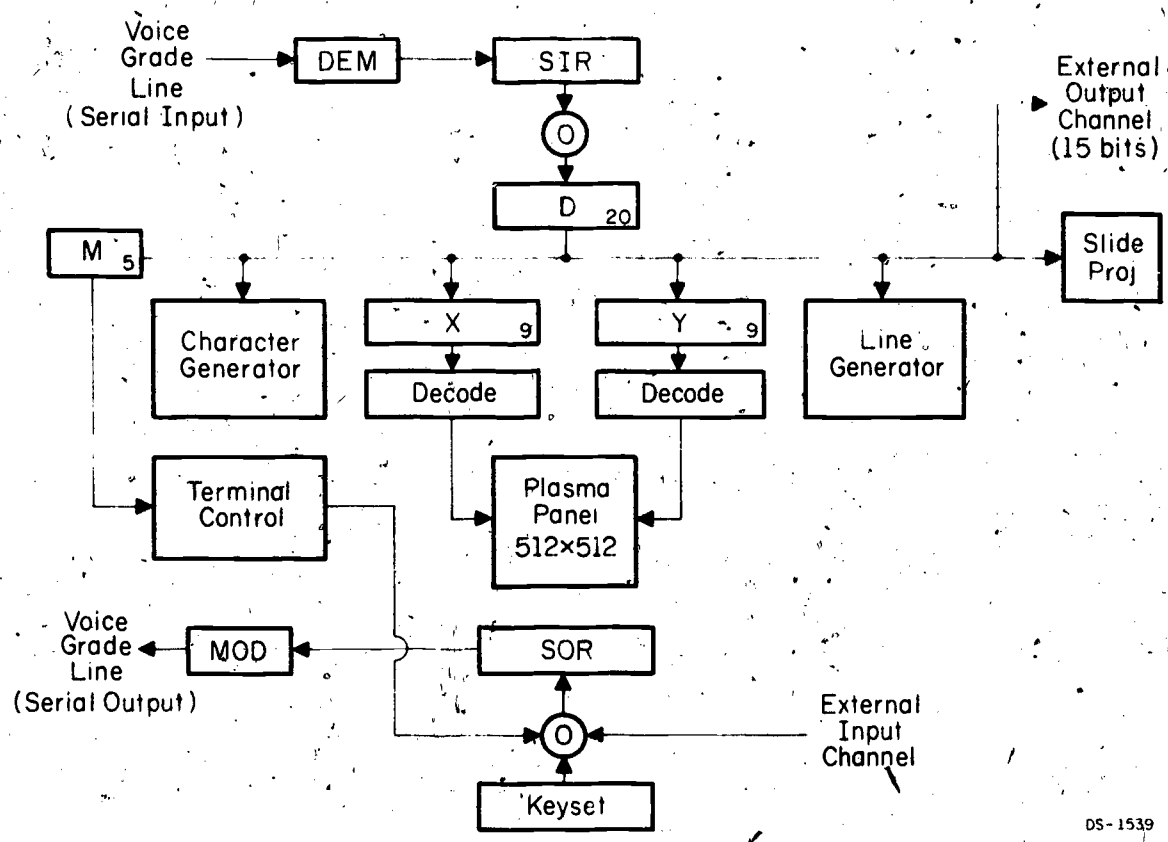

Figure 1. Terminal Block Diagram

is a 8 1/2-inch square panel containing 512 addressable points along each axis or a total of 262,144 points. The address of any point on the panel is specified by the contents of the 9 bit X and Y registers. The outputs of these registers are sent to the decoding and driving circuits which drive the display panel.

The line generator contains the circuits used in plotting lines on the panel. Lines of any length may be drawn at the rate of 60 lines per second.

The character generator contains four memories each containing the points for plotting 64 characters or a total of 256 characters. Two of the memories are read-only memories (ROM) and two are random access (RAM). In the latter case the memories are loaded by the computer with special character or graphical data as required by the terminal user. Characters are plotted at a rate of 180 per second.

A 64 character keyboard provides the terminal operator with an input link to the computer center. Data from the keyboard is entered into the serial output register (SOR). From the SOR data is shifted into the modulator where it is encoded as an fm signal for transmission to the computer center.

Three additional inputs to the SOR are provided. One port permits Terminal Control to transmit terminal condition information to the computer while the other ports provide access to the computer center for externally connected equipment.

1.2 Auxiliary Equipment

Three 15 bit output channels are provided to permit operation of external equipment.

One channel is used to transmit data to a random access slide projector[3] which can project slides on the rear of the plasma display panel. The slide projector will contain a 256 slide memory with an access time of .2 second.

A second channel may be used to address an audio response unit. The audio unit will, upon command from the computer center, play back a message to the terminal operator. Up to 15 minutes of prerecorded audio messages may be available with an average access time of .5 second.[4]

Other types of equipment which might be attached to the terminal include printers, or other hard copy devices and various types of data acquisition and recording equipment.

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[3] D. L. Bitzer, R. L. Johnson, and D. Skaperdas, "A Digitally Addressable Random-Access Image Selector and Random Access Audio System," CERL Report X-13, Computer-based Education Research Laboratory, University of Illinois, August, 1970.

[4] Ibid.

CHAPTER 2 - OPERATING MODES

2.0 Word Format

The data to be processed by the terminal consists of 20 bit words with the format shown in Figure 2.0.

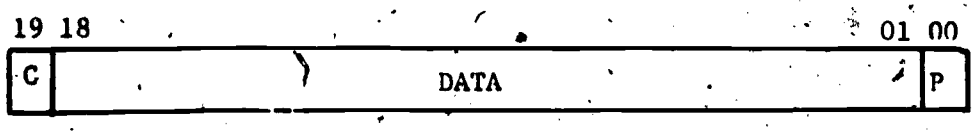


Figure 2.0 Terminal Word Format

Bit 00	Parity bit - even parity
Bits 01 - 18	Data
Bit 19	Control bit - 0 = control word - 1 = data word

Terminal words may be of two types; control words and/or data words. Data words (c = 1) contain the data to be processed by the terminal while control words (c = 0) are instructions used to establish certain conditions within the terminal.

2.1 Control Word

The control word format is shown in Figure 2.1.

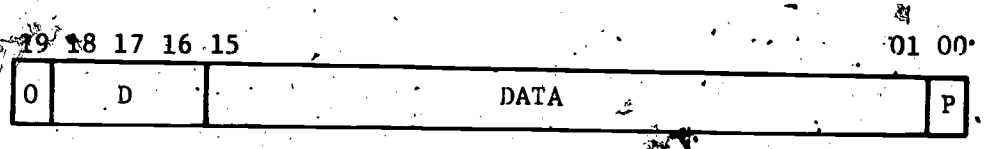
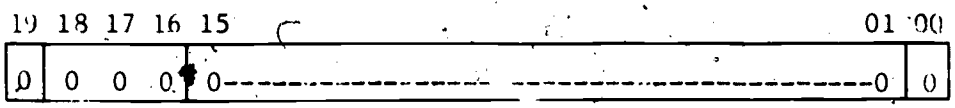


Figure 2.1 Control Word Format

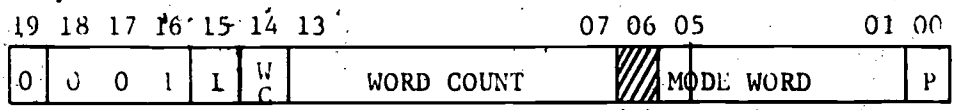
Bits 01 - 15	Data
Bits 16 - 18	Destination of data within the terminal

D = 000 (NOP)



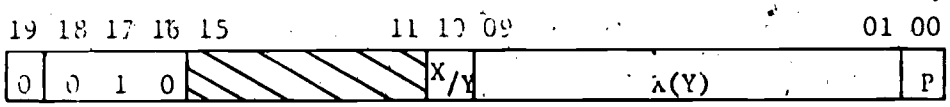
This word is a NOP (no-operation) instruction. The word is input by the terminal but the terminal condition is not altered in any way.

D = 001 (LDM) Load Mode



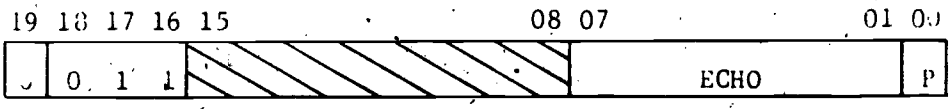
This instruction loads the Mode register (M) with bits 01-05. In addition, if bit 14 (WC) is a "1" the Word Count register will be loaded with bits 07-13. The mode is described in Section 2.2 and the Word Count in Section 2.8. Receipt of an LDM instruction while the terminal is in the ABORT mode will load the Word Count register but will not alter the Mode register. Bit 15 is used to actuate or inhibit external devices attached to the terminal. Receipt of an LDM instruction with bit 15 = 1 will inhibit all inputs from external devices. These Devices will remain inhibited until receipt of an LDM instruction with bit 15 = 0.

D = 010 (LDC) Load Co-ordinate



This instruction loads the X register (bit 10 = 0) or the Y register (bit 10 = 1) with bits 01-09. Bits 11-15 are unused.

D = 011 (LDE) Load Echo



This instruction loads the terminal output register (SOR) with bits 01-07. This word is then transmitted back to the computer center.

Programming Note: This instruction should not be sent to the terminal at a rate greater than once every 32 words. (Once every 64 words if external input devices are present at the terminal.) Exceeding this rate may cause erroneous data to be returned to the computer center.

D = 100 (LDA) Load Memory Address

19	18	17	16	15	11	10	01	00
0	1	0	0			MEMORY ADDRESS		P

This instruction loads the Memory Address Register (MAR) with bits 01-10. Bits 11-15 are unused. This data word specifies the first storage address to be used upon entry into a Mode 2 operation.

D = 101 (SSL) Load Slide

19	18	17	16	15	11	10	09	08	05	04	01	00
0	1	0	1			L	S	X		Y		P

This instruction is used to operate the slide projector. Bits 01-08 select one of 256 slides for display on the plasma panel. Bit 09 controls the projector shutter. For normal operation this bit is always "0". However, if this bit is a "1", the shutter will be closed and remain closed until receipt of a load slide command with bit 09 = "0". Bit 10 controls the projector lamp. The lamp will be turned on if bit 10 is a "1" and off if bit 10 is a "0".

D = 110 (AUD) Load Audio

19	18	17	16	15 ... 01	00
0	1	1	0	AUDIO DATA	P

This instruction is used to control the audio response unit. The audio response unit requires two of these instructions per audio operation. The formats of each of these instructions is described below.

15	14	13	12 ... 06	05 ... 01
1	E	P	TRACK	SECTOR

First audio instruction

Bits 01 - 12	Specify the message starting address; bits 01 - 05 specify one of 32 sectors and bits 06 - 12 one of 128 tracks.
Bits 13 - 14	Specify playback or erase as follows: 00 - do nothing 01 - play message 10 - do nothing 11 - record message
Bit 15	Always "1". Identifies first of two audio instructions.

15	14 ... 08	07 ... 01
	0----------0	MESSAGE LENGTH IN SECTORS

Second audio instruction

Bits 01 - 07	Specify length of message in terms of sectors. One sector equals ∿ 1/3 seconds.
Bits 08 - 14	Unused
Bit 15	Always "0" - identifies second audio instruction.

D = 111 (EXT) Load External Channel

19	18	17	16	15	01	00
0	1	1	1	EXTERNAL DATA		P

This instruction transfers bits 01 - 15 to any equipment attached to the external output channel of the terminal.

2.2 Mode Word

For each mode of terminal operation there is an associated mode word which directs the terminal processing of incoming data. Once placed in any given mode the terminal remains in that mode until receipt of a new LDM instruction. The mode word format is shown in Figure 2.2

05	04	03	02	01
M_1	M_0	W/E_1	W/E_0	S

Figure 2.2 Mode Word Format

Bit 01 — Screen Command. If this bit is a "1", the entire display panel is erased at the time the Mode Word is loaded into the M register.

Bits 02 - 03 — Select write or erase function as follows:

W/E_1	W/E_0	
X	0	Erase
0	1	Write
1	1	Write; suppress all background erase operations. This operation is described in more detail in Section 2.6.

Bits 04 - 05 — Specify operating mode

2.3 Mode 00

Mode 0 is a point plotting mode. Each mode 0 data word (Figure 2.3) specifies the address of a point on the panel to be written or erased. The W/E_0 bit in the mode word determines which operation is performed.

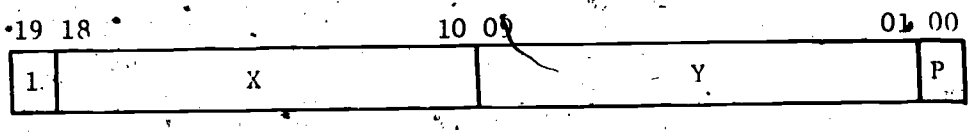


Figure 2.3 Mode 0 Data Word

2.4 Mode 01

Mode 1 is a line drawing mode. Each data word, Figure 2.4, specifies the terminal coordinates of a line, the origin of which is contained in the X and Y registers.

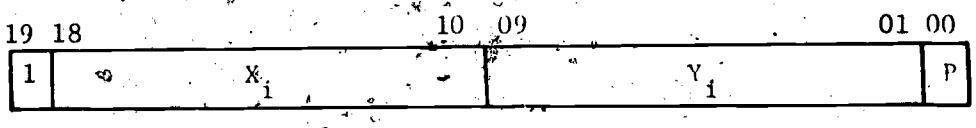


Figure 2.4 Mode 1 Data Format

The terminal point of a given line is also interpreted as the origin of the next line. Line origins may be relocated, however, by the use of the LDC command without exiting from Mode 01.

An example of a Mode 01 operation is shown in Figure 2.5.

2.5 Mode 10

Mode 2 is a load terminal memory mode. Each mode 2 data word (Figure 2.6) contains a 16 bit word to be stored in the memory location specified by the present contents of the memory address register (MAR). Up to 1024 16 bit words may be stored in the terminal. After the data has been stored

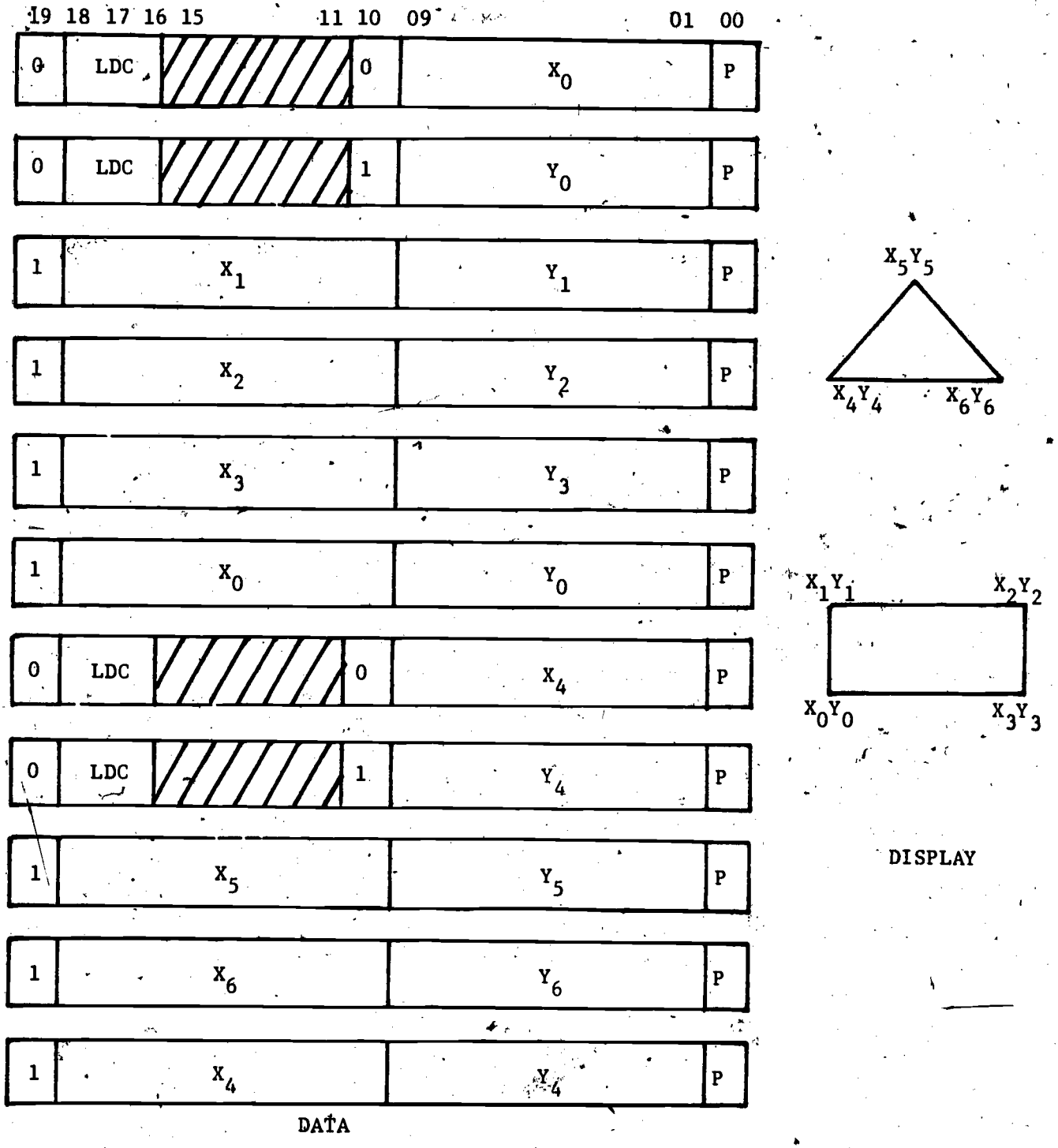


Figure 2.5 Mode 01 Example

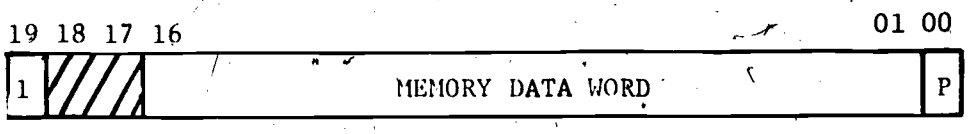


Figure 2.6 Mode 2 Data Word

the MAR is automatically incremented by 1. Thus, data may be stored sequentially in memory by transmitting only Mode 2 data words. The contents of the MAR may be changed at any time via the LDA instruction.

The data, when displayed on the panel, appears as a vertical column with bit 01 at the bottom and bit 16 at the top. The stored data is displayed via Mode 3 which is described in the next section.

2.6 Mode 11

Mode 3 is a character plotting mode. The data words in this mode contain three 6 bit character codes as shown in Figure 2.7.

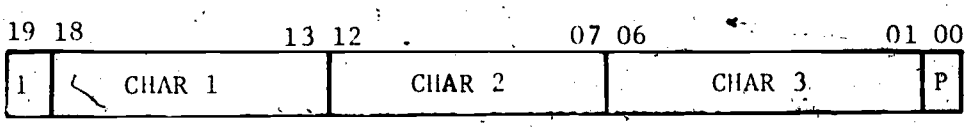


Figure 2.7 Mode 3 Data Word

Four 64 character memories are provided in the terminal. Memories M_0 and M_1 are read-only memories (ROM) which contain the characters shown in Table 2.1. Memories M_2 and M_3 are random access memories (RAM), each containing 512 x 16 bit words, the contents of which are loaded via mode 2. The contents of M_2 and M_3 are processed by Mode 03 as 64 arrays of 8 x 16 bits each. The contents of 8 consecutive addresses are displayed as one character. All characters are displayed within an 8 x 16 matrix as shown in Figure 2.8. The top three and the bottom rows of the matrices for all characters from M_0 and M_1 are always unfilled.

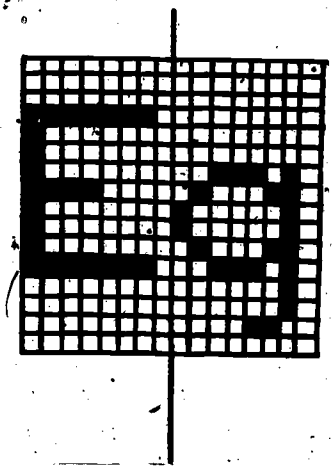


Figure 2.8 Character Matrix

Character write/erase is controlled by the write/erase bits in the mode word. If $W/E_0 = 1$, characters are written; if $W/E_0 = 0$, characters are erased. If $W/E_1 = 0$, the background or normally unfilled portion of each character matrix will be erased, if $W/E_1 = 1$ the background remains unaltered.

Up to 32 lines of 64 characters each may be plotted for a total of 2048 characters. In comparison, a typical page of double spaced type consists of 27 lines of 72 characters or a total of 1944 characters.

2.7 Control Characters

The "uncover" code (77) is used to gain access to 12 control characters. These characters are useful in controlling display format in Mode 3 operations.

Upon receipt of a 77 code, the terminal interprets the next character code as a control character rather than a memory address. Following execution of the control character normal Mode 3 operations are resumed. A description of each control function is given below.

ADDRESS (OCTAL)	MO CHAR	M1 CHAR	ADDRESS (OCTAL)	MO CHAR	M1 CHAR
0	:	#	40	5	↑
1	a	A	41	6	→
2	b	B	42	7	↓
3	c	C	43	8	←
4	d	D	44	9	∿
5	e	E	45	+	Σ
6	f	F	46	-	Δ
7	g	G	47	*	∪
10	h	H	50	/	∩
11	i	I	51	(	{
12	j	J	52	)	}
13	k	K	53	$	&
14	l	L	54	=	≠
15	m	M	55	SP	SP
16	n	N	56	,	|
17	o	O	57	.	o
20	p	P	60	÷	≡
21	q	Q	61	[	α
22	r	R	62	]	β
23	s	S	63	%	δ
24	t	T	64	×	λ
25	u	U	65	←	μ
26	v	V	66	'	π
27	w	W	67	"	ρ
30	x	X	70	!	σ
31	y	Y	71	;	ω
32	z	Z	72	<	≤
33	0	~	73	>	≥
34	1	¨	74	_	θ
35	2	^	75	?	@
36	3	´	76	»	\
37	4	`	77	UNCOVER	UNCOVER

Table 2.1 Character Codes

Uncover (77)

This code instructs the terminal to obey the next character address as a control function. If several uncover codes are sent in sequence, the first non-uncover code will be treated as the control character.

Backspace (10)

This character decreases by 8 the panel x address, i.e., moves one character position to the left. A backspace over a displayed character does not erase the character.

Tab (11)

This character increases by 8 the panel x address, i.e., moves one character position to the right. A tab over a displayed character does not erase the character.

Line Feed (12)

This character decreases by 16 the panel y address, i.e., moves down one character position. A line feed over a displayed character does not erase the character.

Vertical Tab (13)

This character increases by 16 the panel y address, i.e., moves up one character position. A vertical tab over a displayed character does not erase the character.

Form Feed (14)

This character sets the panel address to the upper left corner (x = 0, y = 496). This is the first character position on the top line of the display. No displayed data is erased in this operation.

Carriage Return (15)

This character clears (sets to 0) the panel x address and decreases by 16 the y address. The screen address is thus set to the first character position on the line immediately below the present line. No displayed

data is erased in this operation.

Superscript (16)

This character increases the panel v address by 5. All characters received following this code appear as shown in Figure 2.9. This selection may be removed by receipt of a subscript (17) code. No data is erased in a subscript operation.

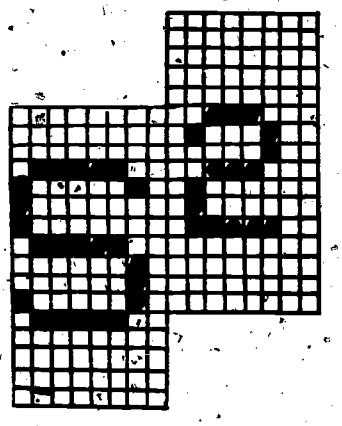


Figure 2.9 Superscript Operation

Subscript (17)

This character decreases by 5 the panel y address. All characters received following this code appear as shown in Figure 2.9.1. This character may be used to remove a superscript selection (16) and the superscript code may be used to remove this selection. No data is erased in a superscript operation.

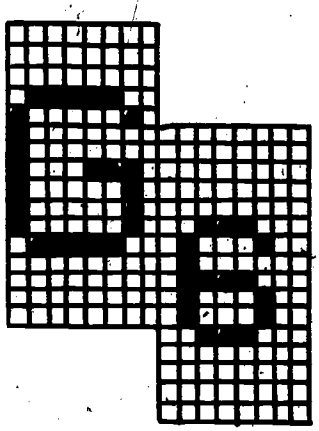


Figure 2.9.1 Subscript Operation

Select M_0 (20)

This code selects character memory 0. All succeeding characters will be read from the memory until receipt of a different memory select code.

Select M_1 (21)

This code selects character memory 1. All succeeding characters will be read from this memory until receipt of a different memory select code.

Select M_2 (22)

This code selects character memory 2. All succeeding characters will be read from this memory until receipt of a different memory select code.

Select M_3 (23)

This code selects character memory 3. All succeeding characters will be read from this memory until receipt of a different memory select code.

2.8 Error Control

Contained within the terminal is a 7 bit Word Count (WC) register, which maintains a record of the number of non-NOP words received by the terminal. Each time a non-NOP word is transferred into the terminal the Word Count is incremented by 1.

Upon receipt of a word with a parity error the terminal enters the ABORT mode of operation. In this mode the terminal transmits the contents of the WC to the computer. The WC will contain the address of the word containing the error.

Once in the ABORT mode the terminal will refuse to accept any further information except for a LDM instruction with bit 14 a "1". Receipt of this word will clear the ABORT mode and return the terminal to normal operation. This method of error control prevents the terminal from processing data in the wrong mode in the event an erroneous mode word is received.

CHAPTER 3 - TERMINAL GENERATED DATA

3.0 Data Sources

Data may be generated by any of four sources within the terminal or by an external device connected to the external input channel. Internal sources of data are:

1. A 64 key keyboard shown in Figure 3.0 with the coding shown in Figure 3.1.
2. The echo code. See LDE instruction in Section 2.1.
3. The Word Count register. See Section 2.8.
4. The Touch Panel. This is an optical input device which permits the terminal operator to enter data into the computer by pointing at areas of plasma panel with his finger.

3.1 Output Word Format

The data transmitted from the terminal consists of 11 bit words with the format shown in Figure 3.2.

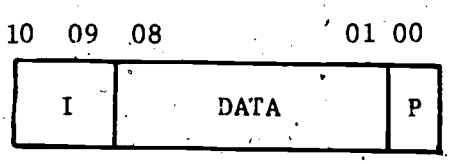


Figure 3.2 Output Word Format

Bit 00	Parity bit - even parity
Bits 01 - 08	Data Field
Bits 09 - 10	Identity source of data

STANDARD KEYBOARD

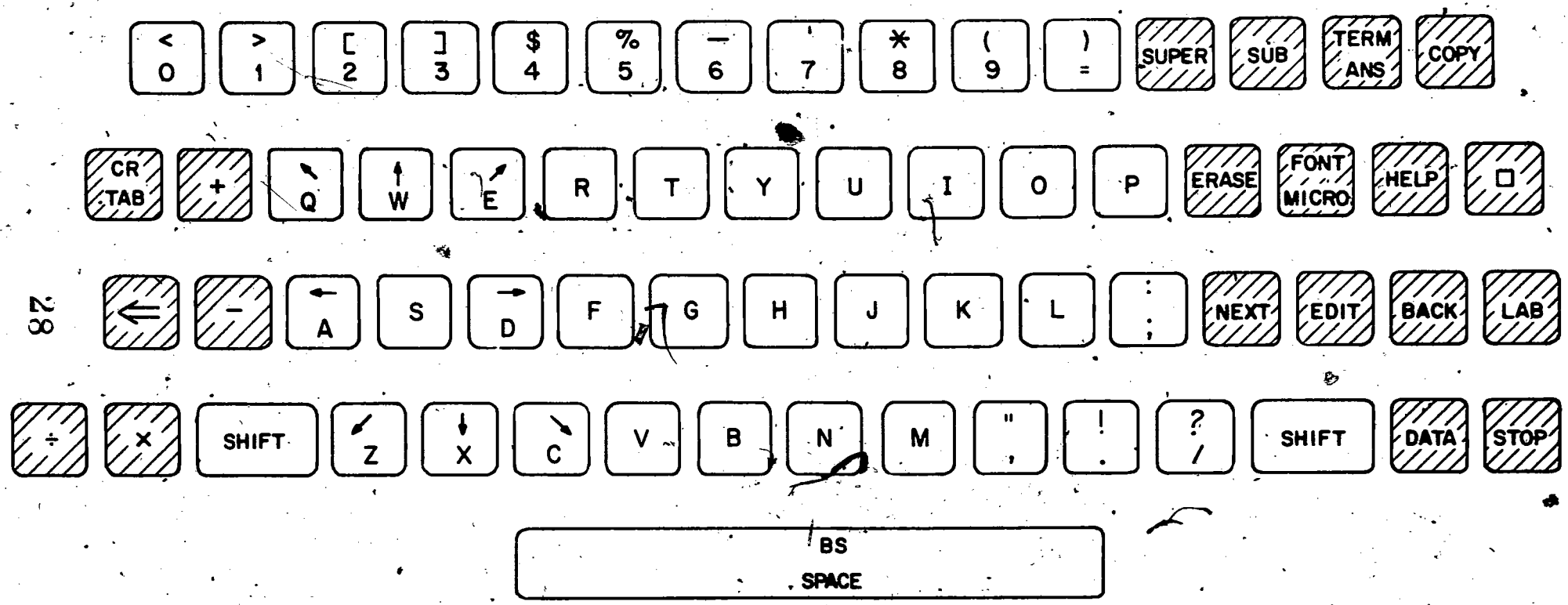
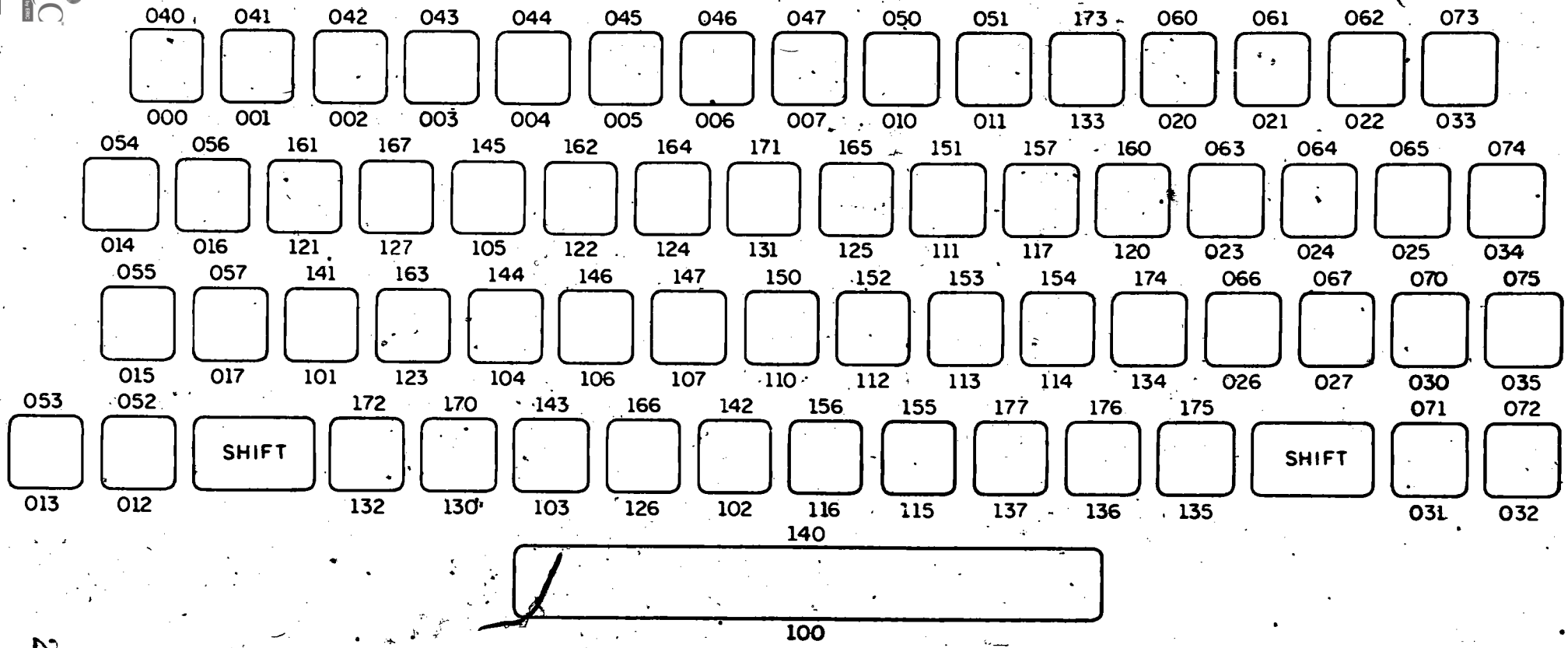


Figure 3.0 Keyboard



NOTE: 1. Each key has two different inputs. The octal number below the box is the input when a key is pressed singly (normal state), and the number above the box is the input when the "Shift" key is held down as a key is pressed (shift state).

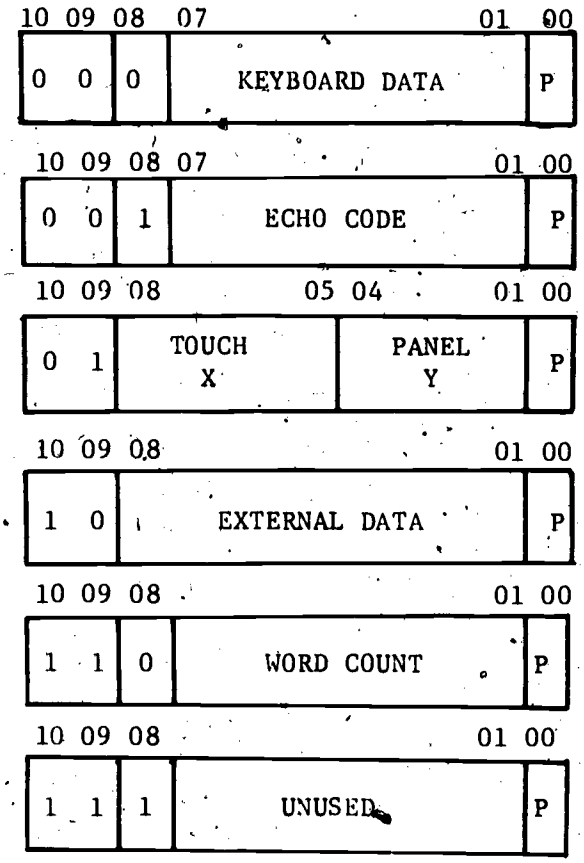
The "Shift" key alone does not initiate input data transfer, but merely causes an addition of 040 (octal) to a normal input.

2. There is a total of 124 different inputs.

3. The input codes 036, 037, 076, and 077 are not used.

Figure 3.1 Keyboard Coding

The word formats for each of the input sources is described below:



Where several terminals (up to 32) share a common link to the computer center the data is sent to a multiplexor which assigns a terminal identity code and adjusts the parity bit before transmitting the data on to the center. In this case, the data has the format shown in Figure 3.3. Except for the identity code, bit assignments are the same as in Figure 3.2.

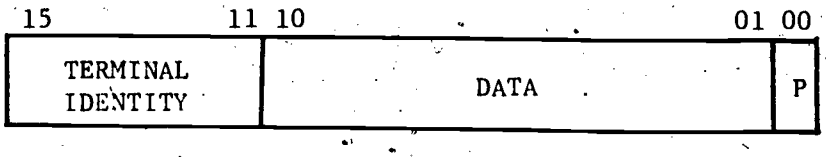


Figure 3.3 Multiplexed Word Format