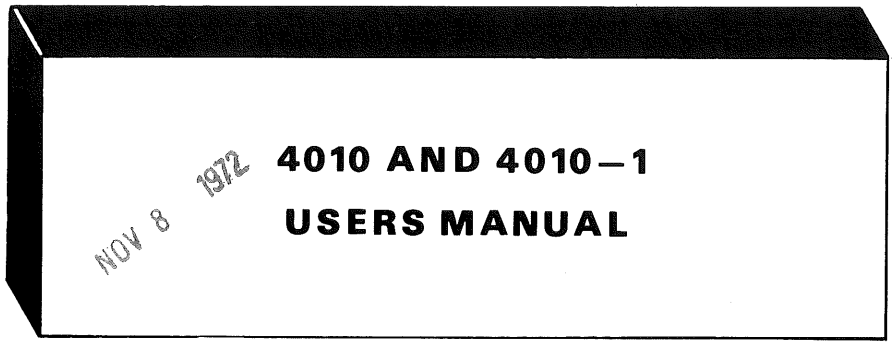
NOV 8 1972

4010 AND 4010–1
USERS MANUAL

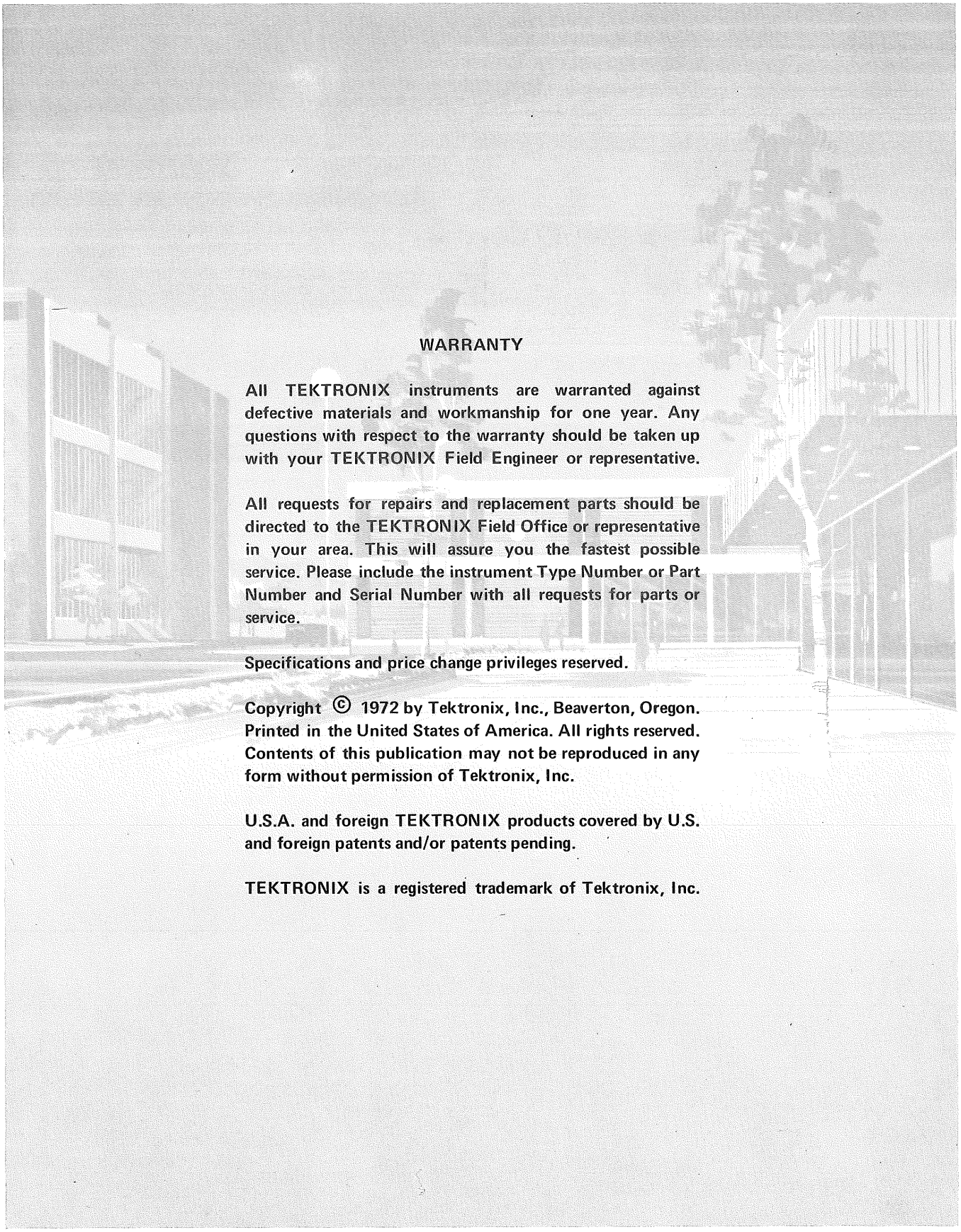
TEKTRONIX® 4010

COMPUTER DISPLAY TERMINAL



Tektronix, Inc. ● P. O. Box 500 ● Beaverton, Oregon 97005 ● Phone 644-0161 ● Cables: Tektronix

070-1225-00



WARRANTY

All TEKTRONIX instruments are warranted against defective materials and workmanship for one year. Any questions with respect to the warranty should be taken up with your TEKTRONIX Field Engineer or representative.

All requests for repairs and replacement parts should be directed to the TEKTRONIX Field Office or representative in your area. This will assure you the fastest possible service. Please include the instrument Type Number or Part Number and Serial Number with all requests for parts or service.

Specifications and price change privileges reserved.

Copyright © 1972 by Tektronix, Inc., Beaverton, Oregon. Printed in the United States of America. All rights reserved. Contents of this publication may not be reproduced in any form without permission of Tektronix, Inc.

U.S.A. and foreign TEKTRONIX products covered by U.S. and foreign patents and/or patents pending.

TEKTRONIX is a registered trademark of Tektronix, Inc.

TABLE OF CONTENTS

About This Manual

Background of the Storage-Tube Terminal

		Page
SECTION 1	SYSTEM DESCRIPTION	1-1
SECTION 2	FAMILIARIZATION AND CHECKOUT	2-1
	Controls	2-1
	Control Familiarization	2-5
	Establishing Computer Communications	2-6
	Modes of Operation	2-6
	Alpha Mode	2-6
	Alpha Mode Checkout	2-7
	Graphic Plot Mode	2-10
	Graphic Plot Checkout	2-10
	Graphic Input Mode	2-13
	Graphic Input Checkout	2-13
	Hard Copy Mode	2-15
SECTION 3	PROGRAMMING CONSIDERATIONS	3-1
	Operating Modes	3-1
	Alpha Mode	3-1
	Optional Character Set	3-1
	Margins	3-1
	Initial Turn-on	3-1
	View & Hold Mode	3-1
SECTION 3	PROGRAMMING CONSIDERATIONS (cont)	
	Graphic Plot	3-2
	Graphic Input	3-9
	Hard Copy Mode	3-11
	ASCII Code Functions	3-11
	Control Characters	3-11
	Strappable Options	3-11
SECTION 4	ACCESSORIES AND ADDENDUM	4-1
SECTION 5	APPENDIX	5-1
	Installation	5-1
	Desk-Top Operation	5-1
	Display Mounting Procedure	5-1
	Safety Considerations	5-2
	Establishing Computer Connection	5-3
	Interfacing Information	5-5
	Minibus Structure	5-5
	Interfacing Considerations	5-5
	Line Names	5-7
	Data Communication Interfacing	5-11
	Tektronix Data Communication Interface	5-12
	Additional Interfaces	5-14
	Glossary of Terms	5-15
	Index	5-18

About This Manual

This manual is to acquaint the new user with the capabilities and operation of the Tektronix 4010 and 4010-1 Computer Display Terminals. The 4010-1 is the same as the 4010 except that the 4010-1 has additional capability of using a Hard Copy unit. References to the 4010 also refer to the 4010-1.

Section 1 contains a physical description and an explanation of on-line terminal operation, followed by section 2 which contains a description of the terminal controls and a control checkout. The control checkout will familiarize the new user with the operation of the controls by showing what can be expected when a key or switch is activated.

The third section describes programming considerations that must be kept in mind when writing a program. The information in this section will pertain mainly to the programmer.

Section 4 is reserved for additional operating information and changes. Additional operating information about your accessories and optional interfaces will be included.

Section 5 is an appendix section containing information not found in the other sections and includes Interfacing information, a Glossary and an Index.

Ⓐ

Background of Storage-Tube Terminal

Since its founding in 1946, Tektronix has been dedicated to research and development in electronic instrumentation. It has brought to the scientific and engineering community an ever-increasing capability for display of waveforms. This intense activity has led to a number of related developments, including, prior to 1960, the direct-view storage tube. This device was first used in the Tektronix 564 oscilloscope in 1963 and, in 1968, was introduced for general use as the 601 storage-tube monitor. Further development resulted in the introduction of the larger 611 storage tube.

This device met with immediate acceptance in the computer-display market and was incorporated into a number of instruments and terminals. In 1969, Tektronix released the T4002 Terminal, incorporating the display.

The usefulness of the Tektronix computer terminal was expanded by the introduction in 1970 of the 4601 Hard Copy Unit. This unit used the storage tube to output an electrical representation of the on-screen display in a manner suitable for hard-copy reproduction.

The 4002A Terminal, an improved version of the T4002 Terminal followed in 1971.

Fig. 1-1. 4010 Computer Display Terminal.

SECTION 1
SYSTEM DESCRIPTION

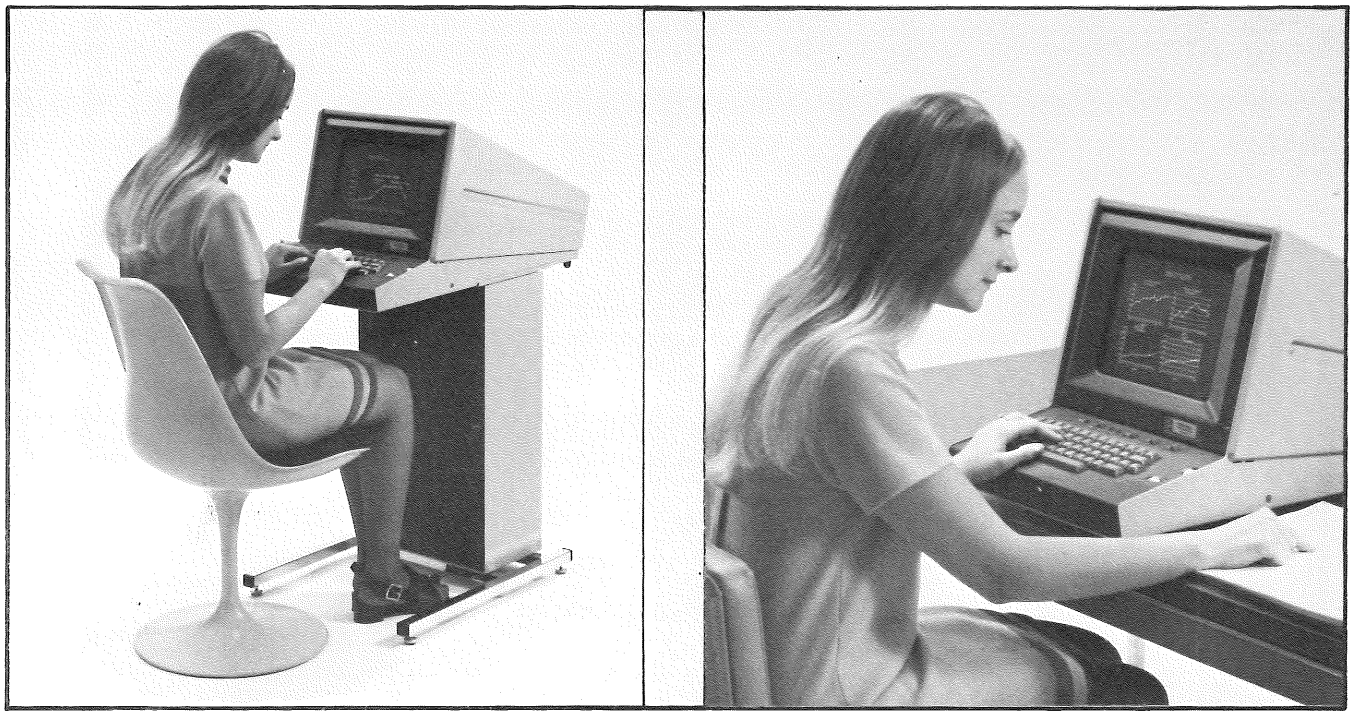


Fig. 1-2. Operating the 4010.

The 4010 Computer Display Terminal is a communication link and display device for use with a wide range of computer systems. It provides the user with an economical device that combines flexibility and ease of operation.

The 4010 consists of a display and a pedestal section. The display section contains the screen, keyboard, and operating controls. The pedestal section contains the electronic circuitry to operate the display section and to communicate with the computer. The display section can be removed from the pedestal section for desk-top operation with a maximum separation of about 5 feet.

From a remote location, the 4010 can be connected via telephone lines to the computer, or at the computer location, the 4010 can be connected directly to the computer. The 4010 can be used with most commercial timesharing systems. Thus the computer can be directly controlled by the user of the Terminal.

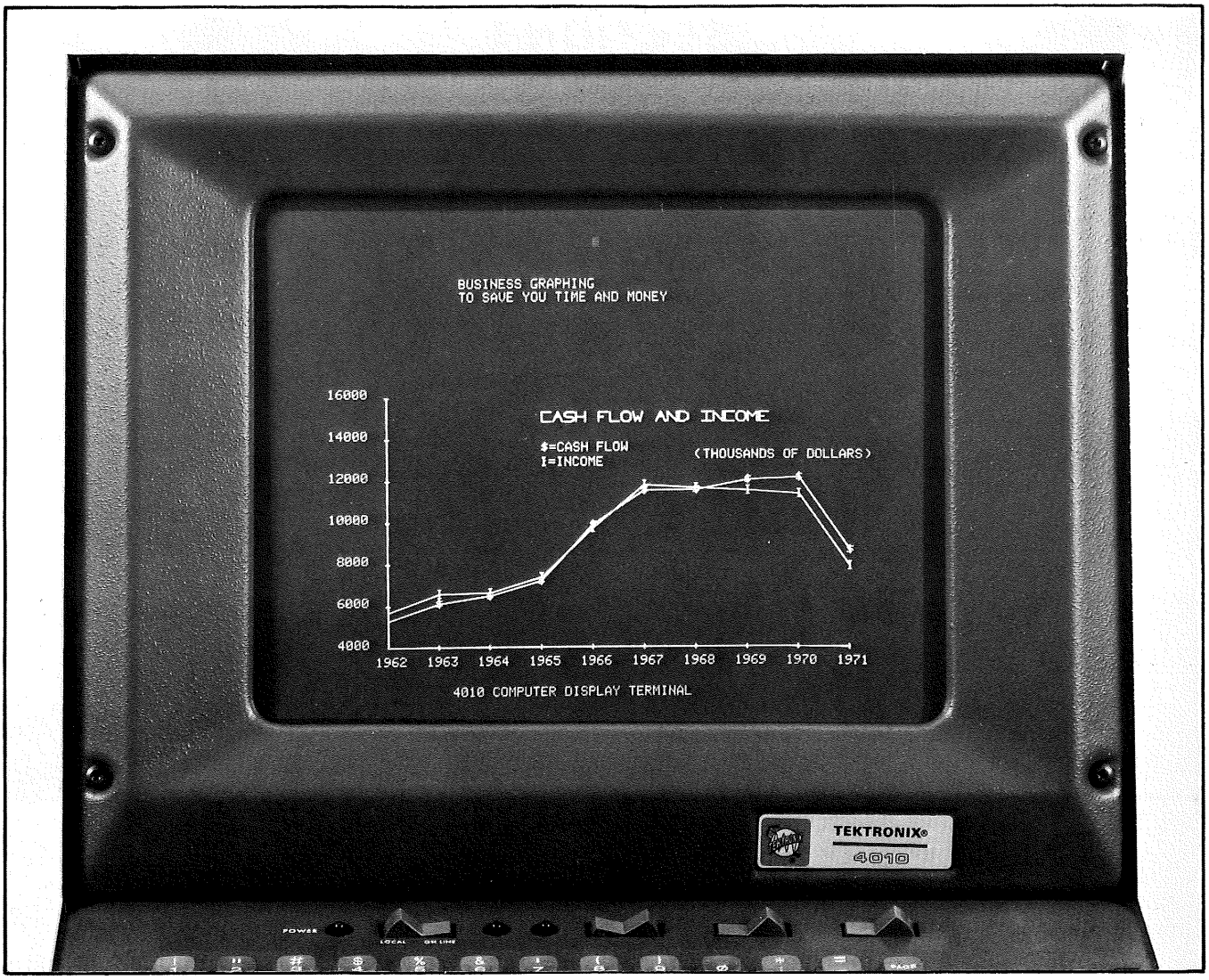


Fig. 1-3. 4010 Business Display.

The computer can be programmed with special instructions (Software) designed for your application. By understanding the correct format and a few simple commands, the user controls the computer (by keyboard keys, switches, and special keys), telling it what information is desired, what operation to perform, and how to display the answer on the display screen. The format and command information for the computer are given with the Software instructions, or as an operator only, the instructions may be given to you on a "Program sheet".

The user controls the program from the keyboard and the computer's results are sent back to the Terminal display for viewing. The computer generates answers in the form of numbers and letters. The 4010 can display these results directly in the alphanumeric mode, or they can be displayed in the form of graphs and pictures using the graphic plot mode of the Terminal.

This combination of graphic and alphanumeric display provides a powerful extension of the

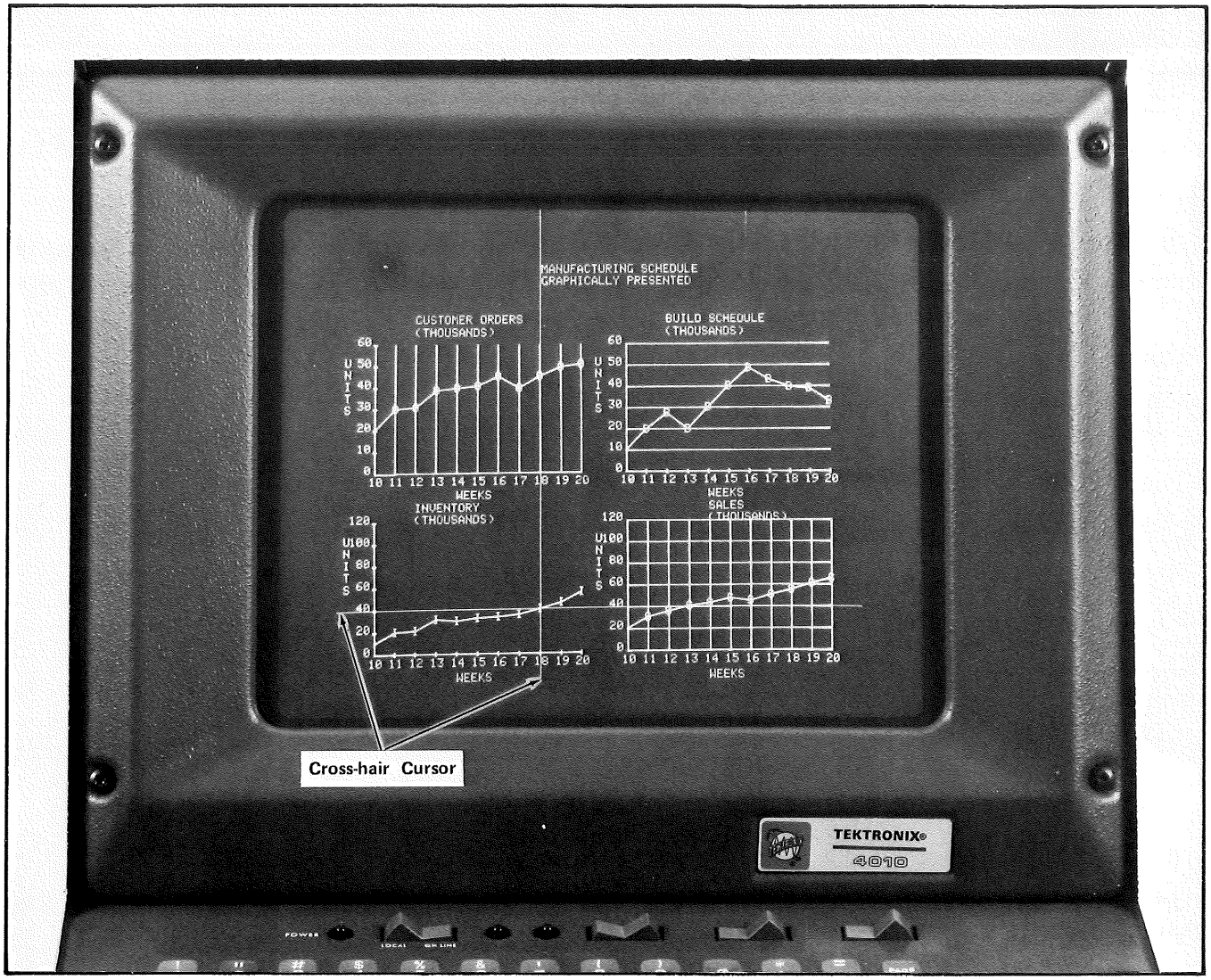


Fig. 1-4. 4010 Display showing the Cross-hair cursor.

man-machine interface. Information such as names, addresses and account information is best displayed directly. Data such as sales value which show historical performance can best be seen as a graph plotted against time.

Sometimes the program may request the user to send back the location of a specific point on the display screen, such as to select one item from a list of options. This mode, called Graphic Input, is another mode of graphic operation incorporated in the 4010. Two non-storing lines are drawn on the display to form a cross-hair cursor. The user positions the lines by using the thumb-wheel controls on the keyboard. He then pushes a selected key on the keyboard and the location of the intersection of the cross-hairs is transmitted to the computer.

Another mode of operation with the 4010-1 is the use of the Hard Copy unit to generate a permanent copy of the displayed data. The Hard

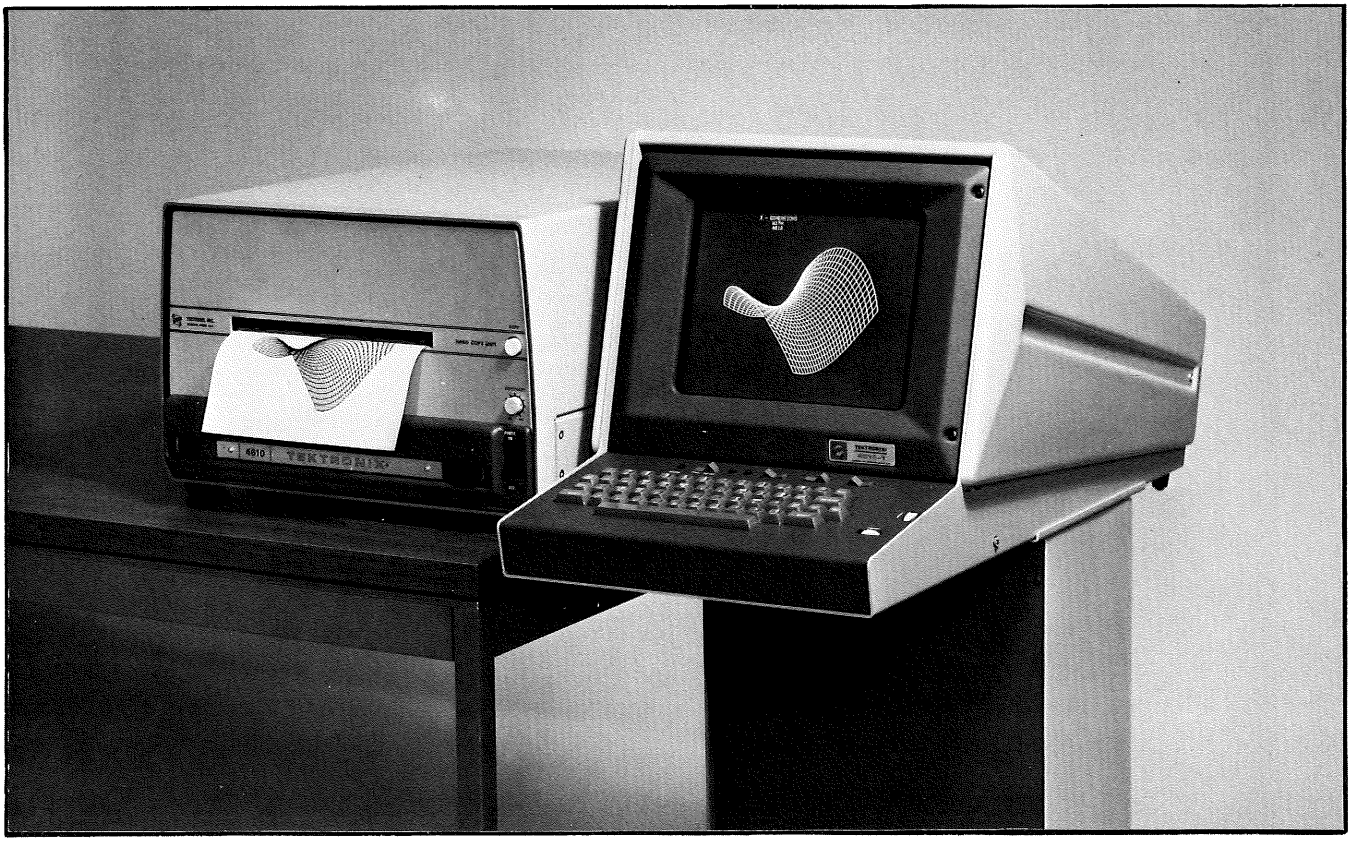


Fig 1-5. 4010-1 with Hard Copy unit.

Copy unit can be activated from the Terminal or from the computer.

In summary, there are four modes of operation.

1. Alphanumeric (Alpha) Mode. (To display printing characters.)

2. Graphic Plot (Graph) Mode. (To display lines for drawings.)

3. Graphic Input (Gin) Mode. (To the computer from the display using the cross-hair cursor.)

4. Hard Copy (Make Copy) Mode. (With 4010-1 and a Hard Copy unit.)

From this section, the new user should have a better understanding of system operation. Explanation of the controls and their operation is given in the next section.

SECTION 2

FAMILIARIZATION and CHECKOUT

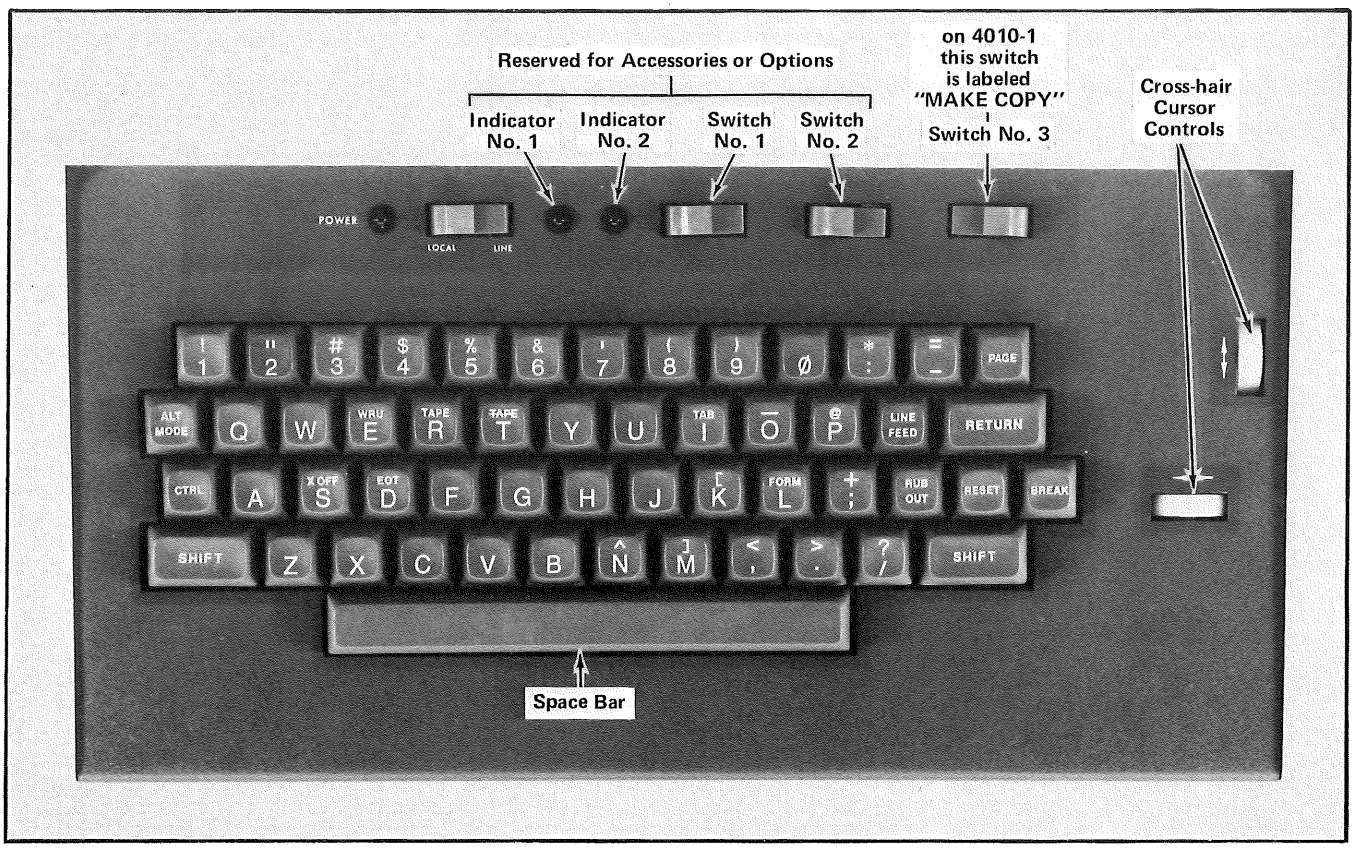


Fig. 2-1. 4010 Controls.

CONTROLS

General

The controls are located on the display unit, with the exception of the POWER switch which is located in the pedestal section. The controls consist of indicators, switches, special function keys and a teletype like keyboard. A description follows. By referring to the photographs you will be able to identify each key as it is being discussed.

Indicators

POWER lamp	Indicates red when Terminal power is applied.
Indicator lamp 1, Indicator lamp 2	Their specific use and indication are determined by the accessories and optional equipment that are used.

Switches

POWER switch	Turns the Terminal power on.
LOCAL/LINE switch	A two-position switch. In the LOCAL position, the terminal is unable to communicate with the computer. This allows the user to send alphanumeric characters to the screen from the keyboard. In the LINE position, with the Terminal connected to the computer, communication with the computer may proceed.
Switch 1	Reserved for use with accessories or optional equipment.
Switch 2	Reserved for use with accessories or optional equipment.
Switch 3	A momentary switch labeled HARD COPY used on the 4010-1 to start a Hard Copy unit.
HC Int	Hard Copy Intensity, a screwdriver adjustment, located on the left side of the pedestal section, is used as a hard copy adjustment for the 4010-1 and Hard Copy Unit. The adjustment procedure is as follows: (1) Adjust HC Int just below the point where the Hard Copy scanning signal starts to write on the 4010-1 screen.

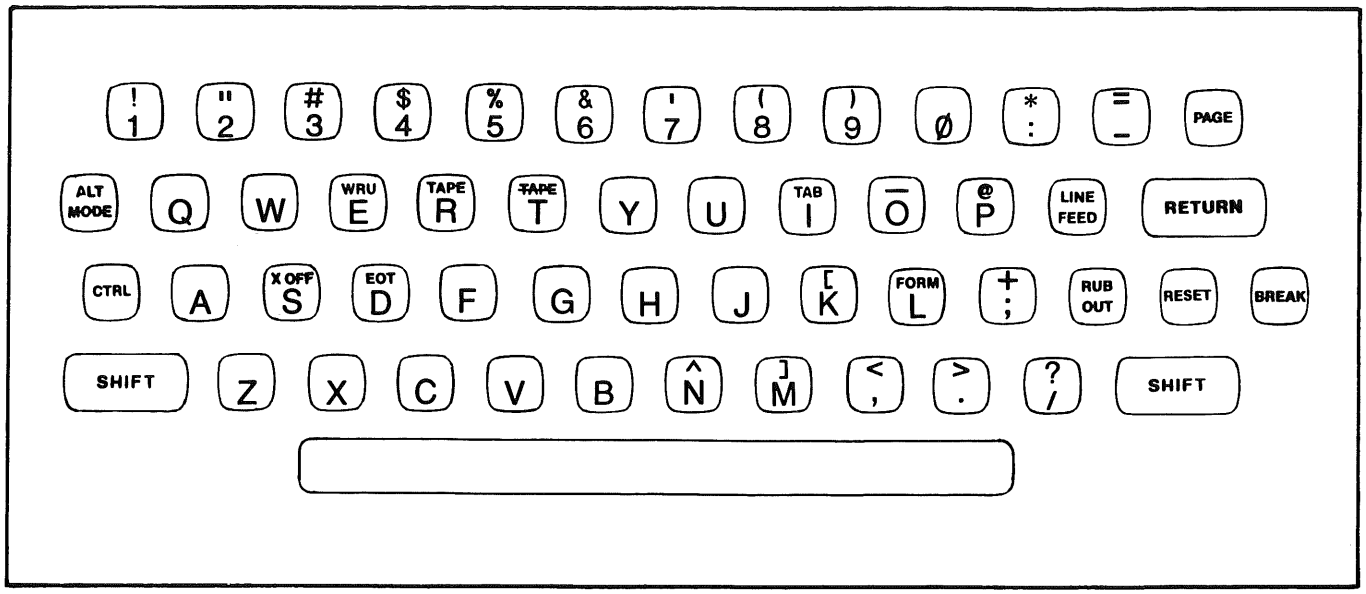


Fig. 2-2. 4010 Keyboard keys.

Special Function Keys

ALT MODE

Transmits the ASCII character (right brace). Performs a function dependent upon the computer program.

BREAK

This key may interrupt the computer when it is sending data to the display. The interrupt operation is dependent upon the Interface and the computer system. With the Data Communication Interface, pressing the Break key causes the Interface to transmit a 16 bit long Spacing signal.

PAGE

When pressed, all information will be erased from the display. The alpha position cursor will move immediately to the upper-left corner of the screen (HOME). If operating in a graphics mode, pressing PAGE will reset the Terminal to the Alpha Mode. Nothing is transmitted to the computer when this key is used.

RESET

When pressed, the Alpha position cursor will be set to HOME without erasing the display. Nothing is transmitted to the Computer when the RESET key is used.

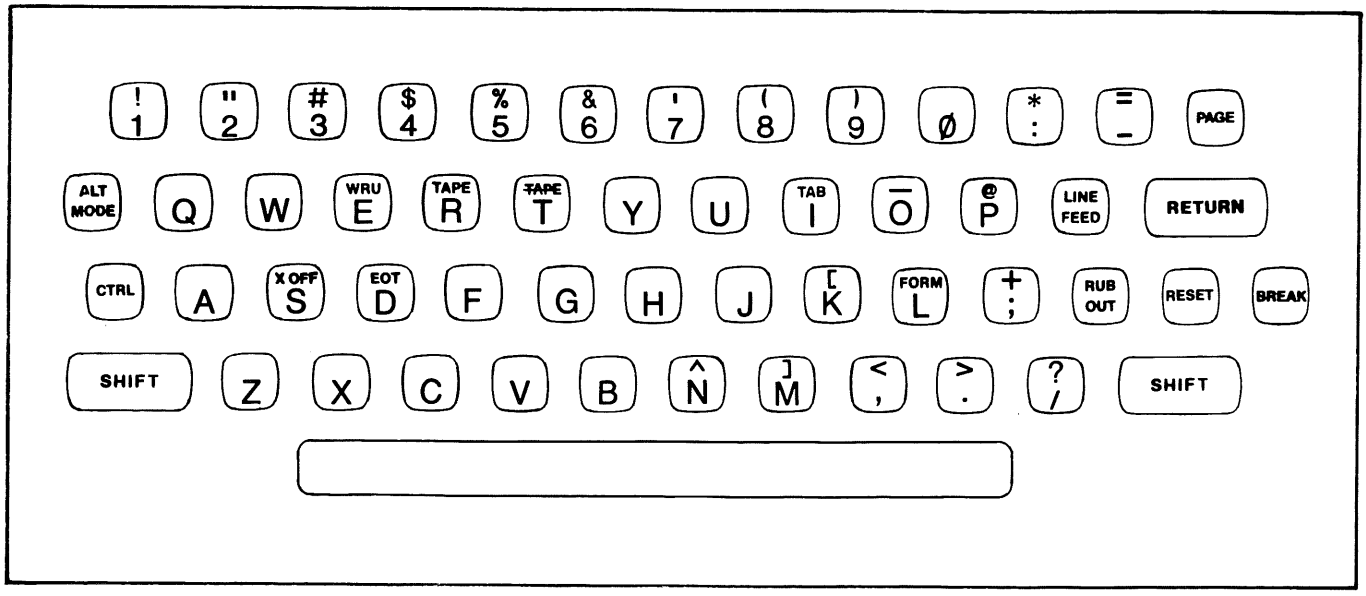


Fig. 2-3. 4010 Keyboard keys.

RETURN

When pressed, transmits the ASCII character CR (carriage return). If the CR is returned by the computer or locally returned, the Alpha position cursor will be sent to the starting point of the line which is normally at the left side Margin 0; however, if Margin 1 instead of Margin 0 is being used, the Alpha position cursor will be sent to Margin 1. Margin 1 is a left hand margin which is located vertically at the center of the screen.

RUB OUT

The Rubout is an ASCII character and DEL is transmitted, though not displayed. The function it performs is dependent upon the system program.

SPACE BAR

When pressed, transmits the ASCII character SP (Space). If the SP is returned by the computer or locally returned, the Alpha cursor will move one space to the right.

SHIFT

The Shift key is not used to obtain upper case. It is used to obtain the various symbols, ", #, $, etc. It is also used in conjunction with the CRTL key to obtain some control characters. In addition to these normal functions, the SHIFT key resets the Hold mode to permit viewing of the display.

CRTL

This key will activate the control characters. Control characters are non-displayed command information entered into the computer and/or Terminal from the keyboard. Control characters provide switching between the operational modes as well as controlling specific operations. Two keys must always be pressed to obtain a control character. (In some cases a third key, the SHIFT key, must also be pressed.) For example, to initiate backspacing of the Alpha cursor, the user must press the CTRL key and at the same time press the H key. (For complete information on all control functions used by the 4010, see the Programming Considerations, section 3.)

Cross-hair Cursor Controls. The cross-hair cursor controls are the two thumb-wheel rollers to the right of the keyboard. When the cross-hair is displayed, the user can position it over the face of the display with these two controls.

CONTROL FAMILIARIZATION

General

The 4010 Computer Display Terminal can be operated in either a local or an on line condition. In the local condition, no information (data) is sent to the computer. In the on line condition, data is sent to and received from the computer, and the results of the data is shown on the display screen. The LOCAL/LINE switch enables one or the other of these two conditions.

Establishing Computer Communications

The 4010 can be connected to a computer by using a normal telephone line, or by connecting it directly to a computer. If a telephone line is used, the user must use a modem unit, and dial the computer, have the LOCAL/LINE switch in the LINE position, to establish the computer link. If the 4010 is connected by a direct connection, all that is required is for the user to switch the LOCAL/LINE switch to LINE. For complete information on establishing the computer connection, refer to section 5.

Modes of Operation

When the proper control characters are received either from the keyboard or the computer, one of the following modes is set:

1. Alphanumeric (Alpha) Mode
2. Graphic Plot (Graph) Mode
3. Graphic Input (Gin) Mode
4. Hard Copy (Make Copy) Mode

ALPHA MODE. In the Alpha mode, the Terminal is used to display any of the printing characters on the keyboard. A non-storing Alpha cursor is displayed on the screen to indicate the next writing position. This is the Alphanumeric or Alpha cursor. The display screen allows up to 35 lines of information with a maximum of 74 characters in each line. There are left and right margins with an automatic carriage return and line feed at the right margin. When first turned on the 4010 will automatically reset to the Alpha Mode. A position on the screen referred to as "HOME" is located in the upper left corner of the display. This is the first line, first character position.

ALPHA MODE CHECKOUT. The following checkout procedure will enable the new user to proceed in a step-by-step sequence through the various Alpha Mode controls and functions. Proceed as follows:

CAUTION

Before operating your 4010, be sure it is properly grounded by using a three terminal power plug. For other installation power requirements, see page 5-2 and 5-3.

Step 1. Switch the LOCAL/LINE switch to LOCAL. This prevents erroneous data from being transmitted to the computer. This inhibits the computer communication link for the purpose of this check-out procedure.

Step 2. Turn on the power. (The Power switch is located on the front of the pedestal.) The POWER lamp will illuminate red. Allow the Terminal to warm-up until the display glows with a bright green tint. This is known as a "fully written condition."

Step 3. Press the PAGE key. Note the "erasure" of the bright green tint and the appearance of the Alpha cursor in the upper left corner (HOME) of the display.

Step 4. Type any of the alphanumeric symbols on the keyboard and note their appearance on the display. Also note the movement of the Alpha cursor to the right.

Step 5. Press the SPACE bar and note the movement of the Alpha cursor to the right, one space each time the bar is pressed.

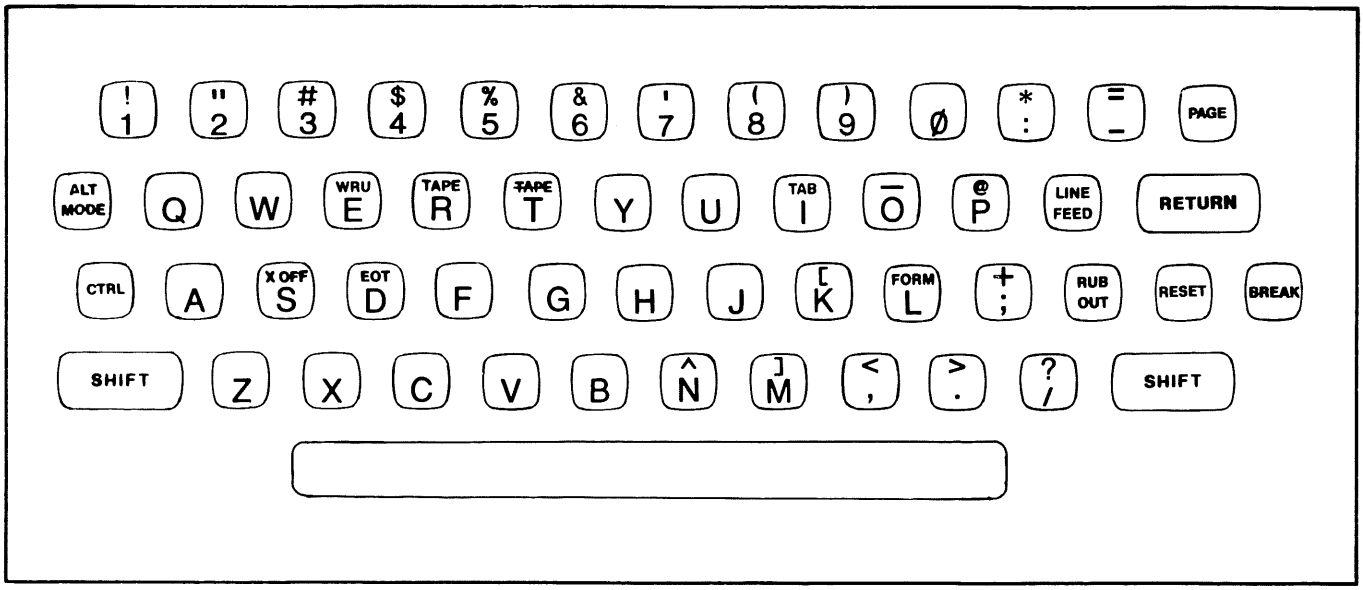


Fig. 2-4. 4010 keyboard keys.

Step 6. Press the CTRL and the H keys simultaneously. Note that the Alpha cursor backspaces one space.

Step 7. Press the RETURN (CR, carriage return) key. Note the return of the Alpha cursor to the left hand margin.

Step 8. Press the LINE FEED (LF, line feed) key and note that the cursor advances to the next line of type.

Step 9. Press the CTRL and TAB I keys simultaneously and note that the Alpha cursor spaces one space to the right. (The same function as pressing the space bar.)

Step 10. Press the CTRL and [K keys and note that the Alpha cursor moves up to the preceding line of type.

Step 11. Press the RESET key. Note that the Alpha cursor moves immediately to the HOME position after the key is released.

Step 12. Using the keyboard character keys and the LINE FEED key, position the cursor away from HOME. Press the PAGE key and note the erasure of all displayed data and the return of the cursor to HOME.

Step 13. Press CTRL and G and note the audible tone from the speaker.

Step 14. Enter a few characters from the keyboard to the display and then stop typing. After about 90 seconds the Terminal will go into a "hold" condition. The hold condition allows the Terminal to dim the display when no new data is being entered. This aids in prolonging the life of the display screen. Pressing the SHIFT key or the entering of any new data will restore the display for viewing.

Step 15. Using the keyboard, continue to enter data until the Terminal reaches the right margin. Upon reaching the right margin, note the automatic carriage return and line feed that positions the Alpha cursor back to the left margin.

Step 16. Center of the page margin called "Margin 1" can be used as a left hand margin. See Fig. 2-5. Margin 1 is automatically set at the end of the 35th line of text when followed by a LINE FEED and RETURN (carriage return). The advantage of using Margin 1 is that you can get two columns of copy: however; if any first column lines extend over one half page they will be covered by the second column.

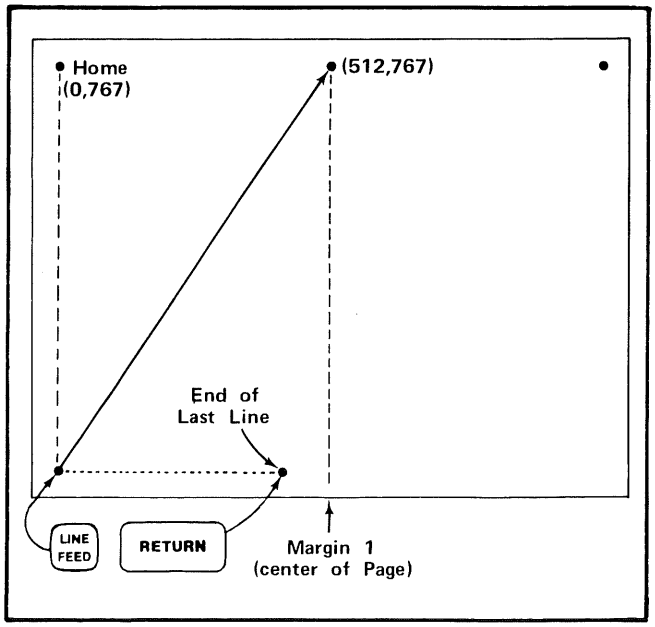


Fig. 2-5. Steps which set up Margin 1 (center of the Page).

GRAPHIC PLOT MODE (GRAPH). In the Graphic Plot Mode, the 4010 uses 1024 addressable points on each axis. Only 780 of these points are visible on the vertical (Y) axis. The addressable points are obtained by sending data in groups of 4 bytes. Each 4 character sequence represents a specific point: for instance, the keys, space bar (RUB OUT) space bar (SHIFT) key (@ P) key, represent the 0,31 position (X = 0 and Y = 31).

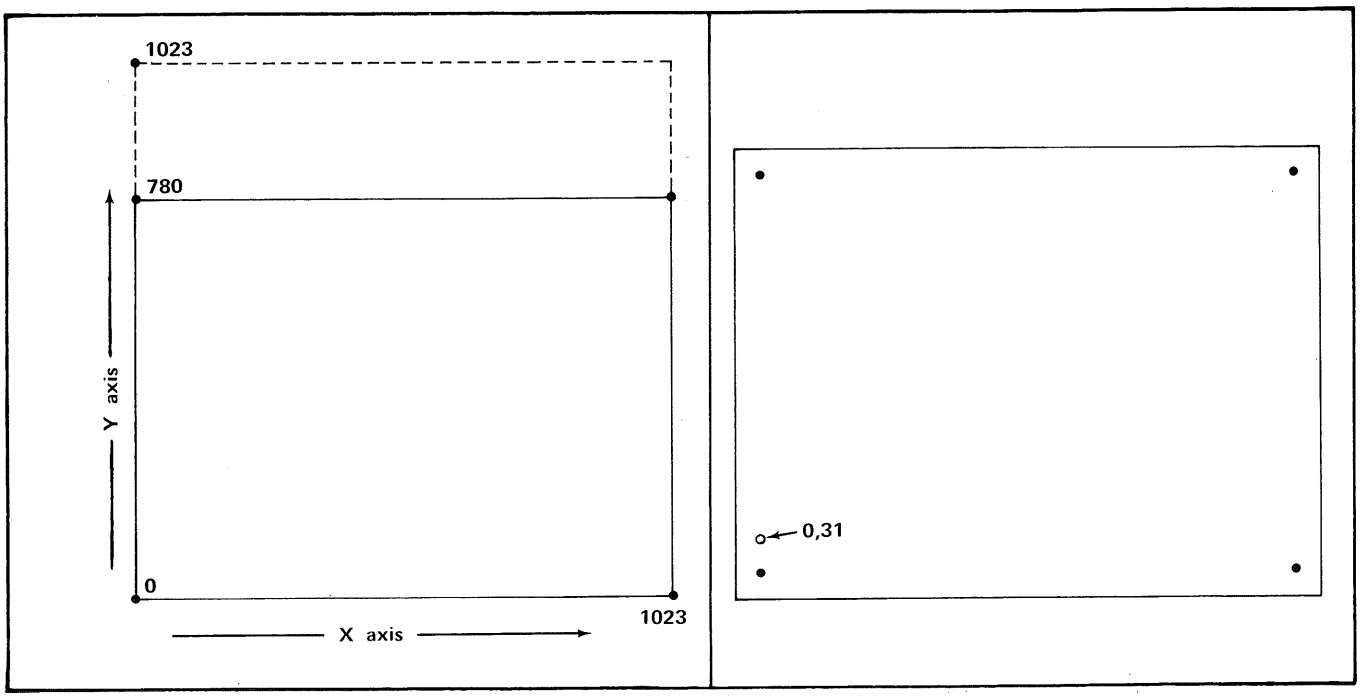


Fig. 2-6. Graphic Plot Area.

Normal graphic plot information comes from the computer. However, it is the purpose of the following checkout procedure to give the user a means of seeing the lines drawn from the 0, 31 position in a rectangle around the display screen as shown in Fig. 2-8.

GRAPHIC PLOT CHECKOUT

Step 1. Insure that the LOCAL/LINE switch is in LOCAL. To enter the Graphic Plot Mode, simultaneously press the CTRL and SHIFT and M keys. Note that the Alpha cursor disappears. Left and right margins will be inhibited; so is the hold circuitry.

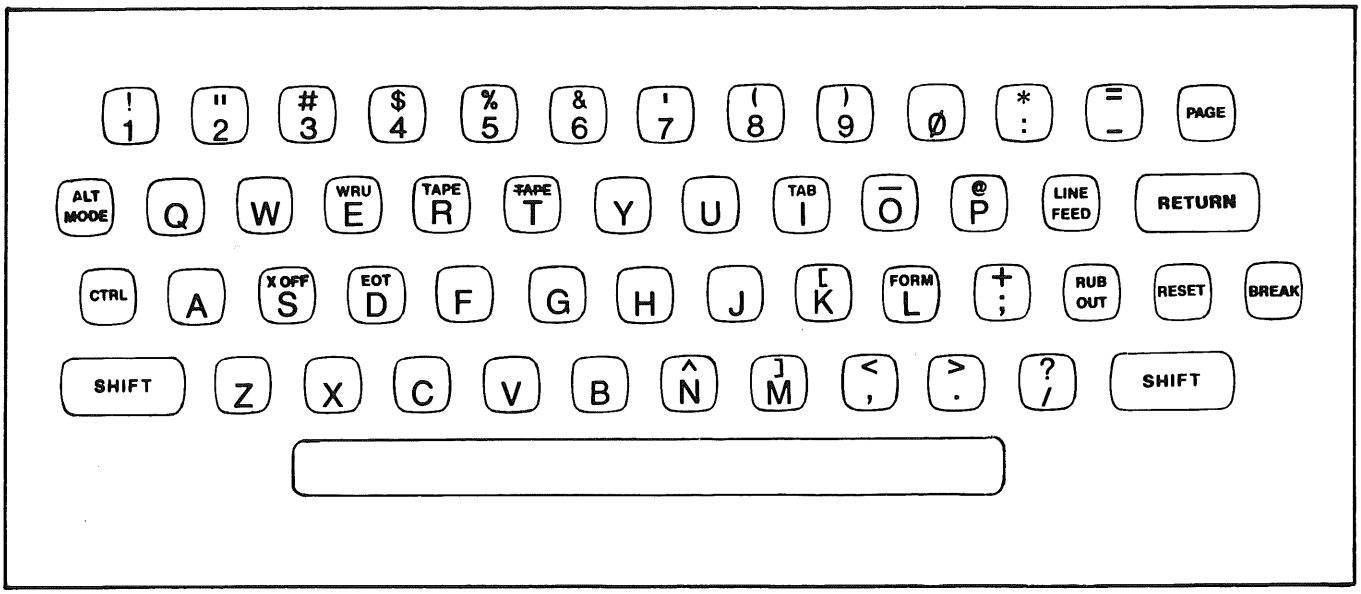


Fig. 2-7. 4010 Keyboard Keys.

Step 2. Enter the characters, Space (by pressing the space bar) RUBOUT (by pressing the RUB OUT key), Space (by pressing the space bar), and @ (by pressing the SHIFT and @ P at the same time). As a result of pressing these keys, four characters are sent, however they are not displayed. These characters are not displayed because the Terminal inhibits the display of address commands. Also notice that no dot or vector is yet visible. This is always true in the case of the first point given.

Step 3. Enter ' 7 RUB OUT space SHIFT @ P and note the line at the left of the display.

Step 4. Enter ' 7 RUB OUT SHIFT ? / SHIFT O and note the line across the top of the display screen.

Step 5. Enter space RUB OUT SHIFT ? / SHIFT O and note the line on the right of the display screen.

Step 6. Enter space RUB OUT space SHIFT @ P and note the line across the lower edge of the display screen.

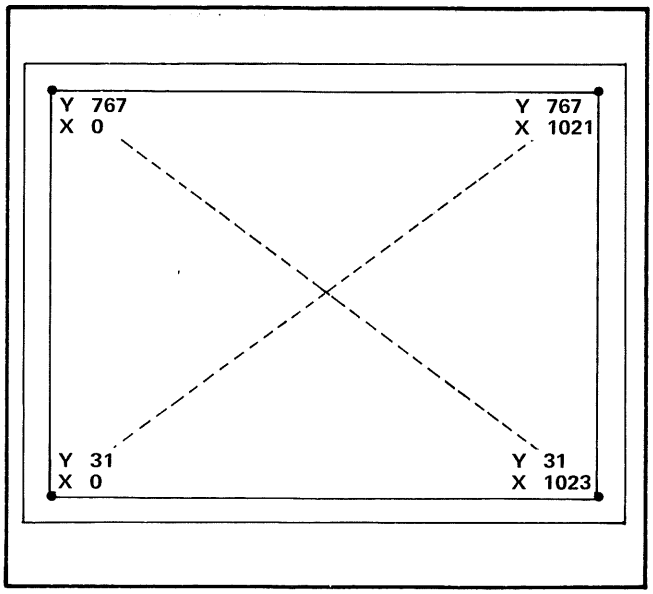


Fig. 2-8. Graphic Checkout Plot.

Step 7. Return the Terminal to the alpha mode, using one of the following function keys or control character keys.

1. CTRL SHIFT Ō simultaneously.
2. CTRL SHIFT K simultaneously; CTRL FORM L
3. RETURN
4. PAGE
5. RESET

CAUTION

A display can be stored up to one hour without permanent damage to the display screen; however, because long storage times cause residual images (shadows that remain after an erasure) the Terminal should be returned to the Alpha Mode when plotting is finished in order to allow the Terminal to go into the hold condition. If a residual image is retained, repeated erasures should restore the screen to normal.

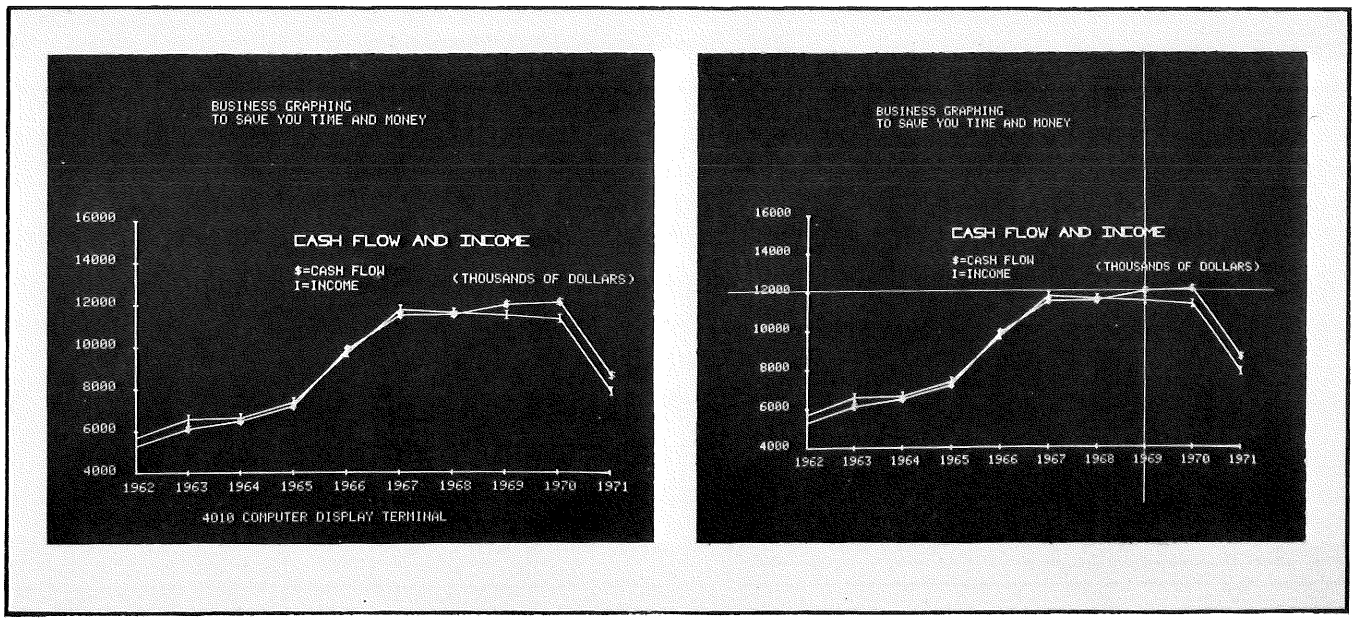


Fig. 2-9. Cross-hair Cursor Operation.

GRAPHIC INPUT MODE (Gin). Graphic Input operation is controlled by the computer except for one operation. That is when the computer program turns on the cross-hair cursor for the operator. The operator then can position the cross-hair cursor to a desired intersect point on the display using the cross-hair controls. When the desired point is intersected, the operator can send the position information of the point to the computer by striking a selected key.

GRAPHIC INPUT CHECKOUT. Because the user should familiarize himself with all the controls, the cross-hair or graphic input cursor can be turned on, in the LOCAL condition, by sending the proper control character from the keyboard.

Step 1. Insure that the LOCAL/LINE switch is in the LOCAL position.

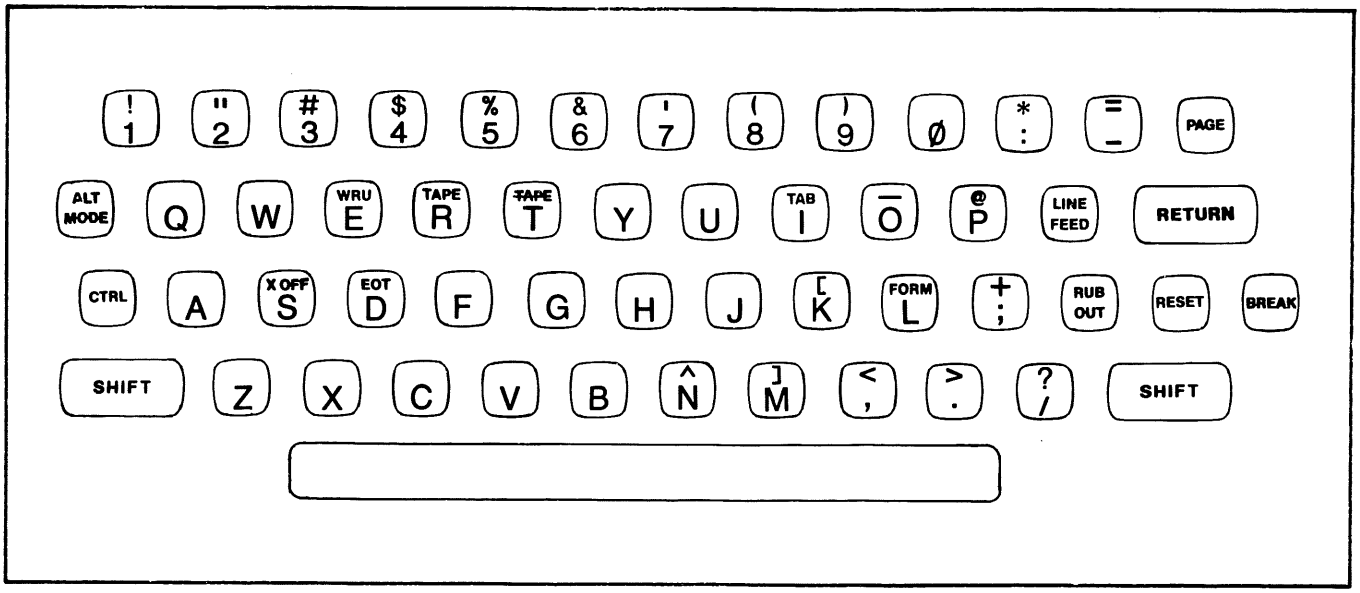


Fig. 2-10. 4010 Keyboard keys.

Step 2. Enter CTRL , SHIFT , K simultaneously, then CTRL Z . Note that after CTRL Z is sent, the cross-hair cursor appears.

Step 3. Using the dual-thumbwheel controls to the right of the keyboard, position the cross-hair cursor over the display area. (When operating on LINE, only points that fall within the movement of the cursor (1024 X 780) can be sent to the computer.)

Fig. 2-11. Cross-hair Controls.

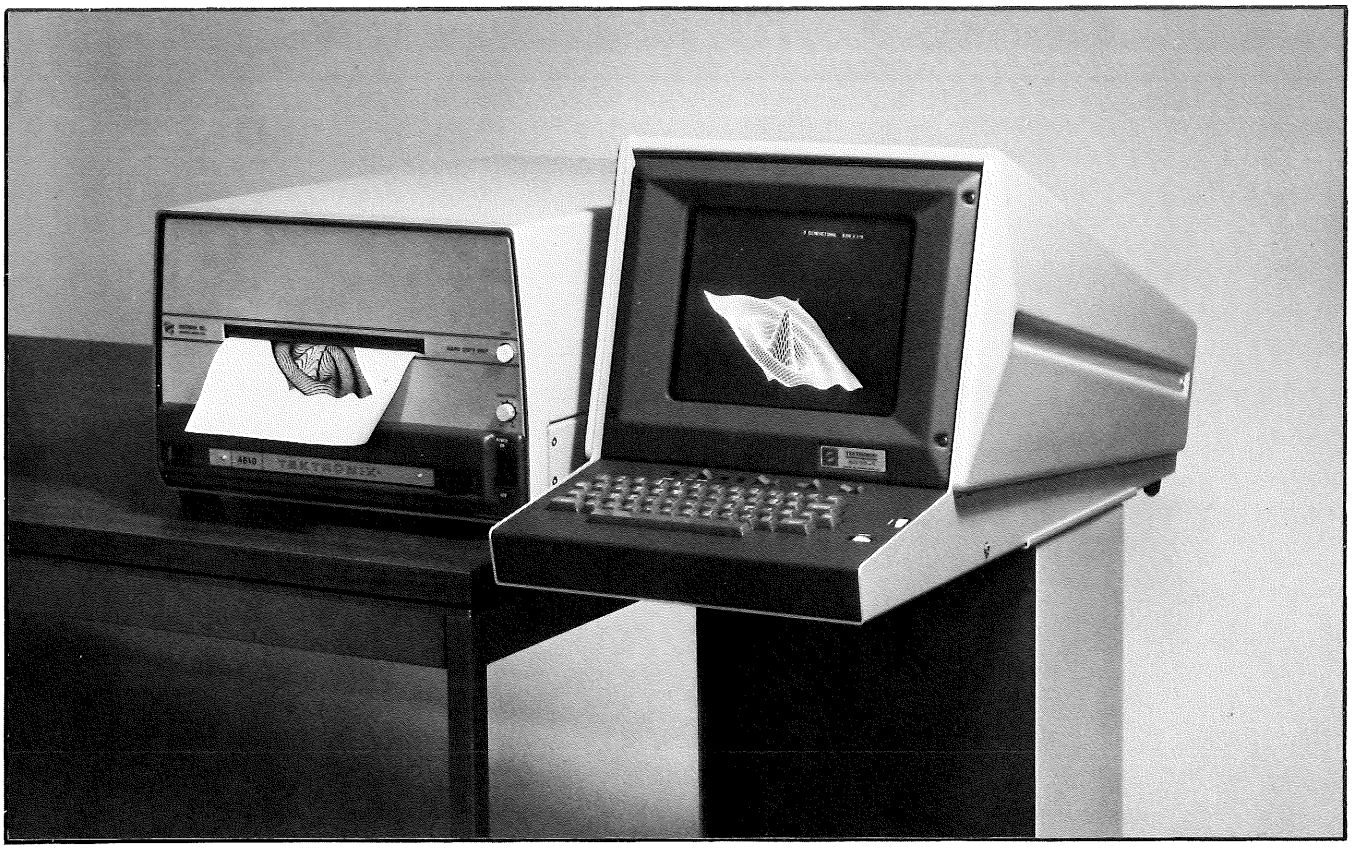


Fig. 2-12. Hard-Copy Operation.

HARD COPY MODE (Make Copy) 4010-1. The Hard Copy Mode is used to generate a permanent copy of the Terminal display. With the 4010-1 and a Hard Copy unit, the user can obtain a hard copy as follows:

Step 1. Check to be sure that the hard copy unit is connected to the 4010-1.

Step 2. After insuring that the terminal display is correct, press CTRL SHIFT [K] simultaneously, then CTRL [W] keys, or press the MAKE COPY switch on the 4010-1. The Hard Copy unit then sends a signal that sweeps the entire 4010-1 display in about 5 seconds. A copy is thus generated. A copy can also be initiated from the computer if the program calls for one.

SECTION 3

PROGRAMMING CONSIDERATIONS

OPERATING MODES

General Information

The operating modes of the 4010 are changed from one to another by the computer data containing the proper control character information to the 4010, or by manual entry from the 4010 keyboard. Entry of data from the keyboard can be restricted to the 4010 terminal only by the use of the LOCAL LINE switch placed in the LOCAL position. The 4010 control character information is given in Table 3-1 and 3-2.

The basic operating and the subordinate conditions are listed in the following outline:

1. Alpha
   - A. View mode
   - B. Hold mode
2. Graphic Plot
   - A. Dark Vector (first vector, normal)
   - B. Light Vector (written)
3. Graphic Input
   - A. Alpha cursor position
   - B. Cross-hair cursor position
4. Hard Copy (4010-1)

Alpha Mode

In the Alpha mode, the 4010 is used to display any of the 64 printing characters including the space character. Lower case letters received will be printed in upper case. A non-storing pulsating cursor is displayed on the screen to indicate the next writing position. The display screen allows up to 35 lines of information with each line containing up to 74 characters.

Optional Character Set. If an optional character set is installed, then the normal character set or the alternate character set may be selected. Selection can be made from a front panel switch or from control characters. (See "Strappable Options", Table 3-3.)

Margins. The left hand margin at position 0 is called Margin 0. When the writing position spaces past position 1023, (the right side of the display) the 4010 initiates a local automatic carriage return and line feed. Margin 1 is a left hand margin which is located vertically at the center of the screen. Margin 1 is automatically set at the end of the 35th line of text when followed by a line feed and carriage return. The advantages of using Margin 1 is that you can get two columns of copy: however; if any first column lines extend over one half page they will be covered by the second column.

Initial Turn-on. Initial turn on places the 4010 in the Alpha mode, and positions the Alpha cursor to the Home location. Home location in Alpha is near the upper left corner of the display with co-ordinates X = 0 and Y = 767. The 4010 will warm up until the display is bright green (fully written condition). Then, to erase the screen so it will display data, send ESC then FF or press the PAGE key.

View & Hold Mode. In the Alpha mode only, if no data is received for about 90 seconds, the 4010

goes from the View mode into the Hold mode. The Hold mode action dims the display, but retains the display information in the display screen material. This action aids in prolonging the life of the display screen. The 4010 will return to the View mode (resetting the Hold mode) by receiving or sending any data, or by the SHIFT keys.

If not in the Alpha mode, the 4010 can be returned to the Alpha mode by US, or ESC then FF, or by PAGE or RESET key.

Graphic Plot (Graph)

In the Graphic Plot mode, the 4010 uses 1024 addressable points in each axis. 780 of these points are visible in the vertical (Y) axis. Figure 3-1 shows the addressable points for the corners of the display and the center of the display. An ASCII GS character gets the 4010 into the Graphic Plot mode. Vectors are drawn from the old address to the addressed point with the exception of the first vector after entering the Graphic Plot mode. This first vector is always dark (unwritten). Additional dark vectors can be drawn at any time by preceeding the address with GS.

Graphic plotting information is sent from the computer in a 4 byte sequence containing High and Low order Y, and High and Low order X. Each byte contains the two tag bits plus 5 binary bits. Each byte thus encodes to an ASCII character.

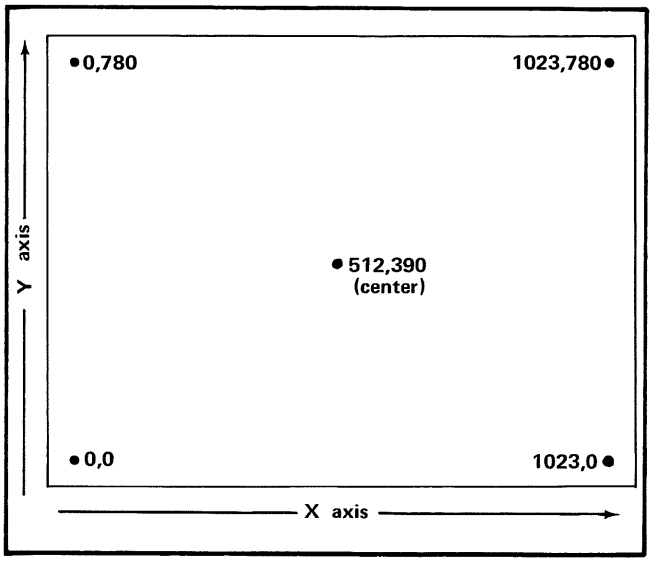


Fig. 3-1. X and Y addressable points for the corners and the center point of the display.

To obtain the 4 ASCII characters for each addressable point on the display, use the instruction as outlined in Fig. 3-2, and the Conversion chart Part 1 through 4 as shown in Fig. 3-3 through 3-6. With X = 0 and Y = 31 as an example of a desired coordinate display, Fig. 3-2 shows the process of selecting the 4 bytes from the Conversion chart Part 1 in Fig. 3-3. The chart is useful for determining the ASCII encoding of a coordinate when it is not convenient to use a computer subroutine.

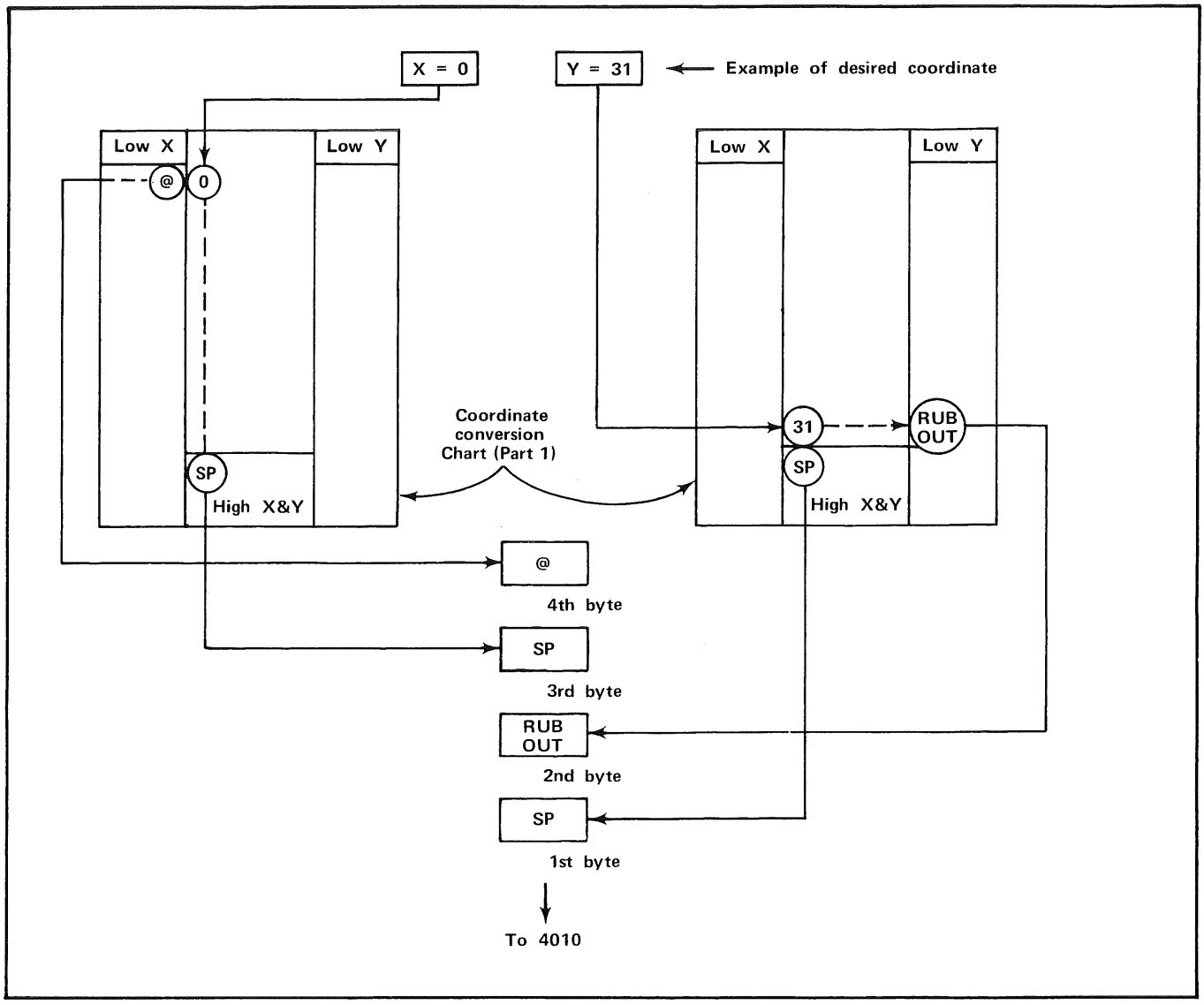


Fig. 3-2. How to use coordinate conversion chart (Figures 3-3 through 3-6) to obtain a 4 byte address from a desired display coordinate.

Low Order X										Low Order Y	
ASCII	DEC.	X or Y Coordinate								ASCII	DEC.
@	64	0	32	64	96	128	160	192	224	`	96
A	65	1	33	65	97	129	161	193	225	a	97
B	66	2	34	66	98	130	162	194	226	b	98
C	67	3	35	67	99	131	163	195	227	c	99
D	68	4	36	68	100	132	164	196	228	d	100
E	69	5	37	69	101	133	165	197	229	e	101
F	70	6	38	70	102	134	166	198	230	f	102
G	71	7	39	71	103	135	167	199	231	g	103
H	72	8	40	72	104	136	168	200	232	h	104
I	73	9	41	73	105	137	169	201	233	i	105
J	74	10	42	74	106	138	170	202	234	j	106
K	75	11	43	75	107	139	171	203	235	k	107
L	76	12	44	76	108	140	172	204	236	l	108
M	77	13	45	77	109	141	173	205	237	m	109
N	78	14	46	78	110	142	174	206	238	n	110
O	79	15	47	79	111	143	175	207	239	o	111
P	80	16	48	80	112	144	176	208	240	p	112
Q	81	17	49	81	113	145	177	209	241	q	113
R	82	18	50	82	114	146	178	210	242	r	114
S	83	19	51	83	115	147	179	211	243	s	115
T	84	20	52	84	116	148	180	212	244	t	116
U	85	21	53	85	117	149	181	213	245	u	117
V	86	22	54	86	118	150	182	214	246	v	118
W	87	23	55	87	119	151	183	215	247	w	119
X	88	24	56	88	120	152	184	216	248	x	120
Y	89	25	57	89	121	153	185	217	249	y	121
Z	90	26	58	90	122	154	186	218	250	z	122
[	91	27	59	91	123	155	187	219	251	{	123
\	92	28	60	92	124	156	188	220	252	|	124
]	93	29	61	93	125	157	189	221	253	}	125
^	94	30	62	94	126	158	190	222	254	~	126
_	95	31	63	95	127	159	191	223	255	RUBOUT (DEL)	127
		32	33	34	35	36	37	38	39		
		SP	!	"	#	$	%	&	/		

High Order X & Y

Fig. 3-3. Coordinate Conversion Chart Part 1 of 4. (For conversion instructions see Fig. 3-2.)

Low Order X ASCII	DEC.	X or Y Coordinate								Low Order Y ASCII	DEC.
@	64	256	288	320	352	384	416	448	480	`	96
A	65	257	289	321	353	385	417	449	481	a	97
B	66	258	290	322	354	386	418	450	482	b	98
C	67	259	291	323	355	387	419	451	483	c	99
D	68	260	292	324	356	388	420	452	484	d	100
E	69	261	293	325	357	389	421	453	485	e	101
F	70	262	294	326	358	390	422	454	486	f	102
G	71	263	295	327	359	391	423	455	487	g	103
H	72	264	296	328	360	392	424	456	488	h	104
I	73	265	297	329	361	393	425	457	489	i	105
J	74	266	298	330	362	394	426	458	490	j	106
K	75	267	299	331	363	395	427	459	491	k	107
L	76	268	300	332	364	396	428	460	492	l	108
M	77	269	301	333	365	397	429	461	493	m	109
N	78	270	302	334	366	398	430	462	494	n	110
O	79	271	303	335	367	399	431	463	495	o	111
P	80	272	304	336	368	400	432	464	496	p	112
Q	81	272	305	337	369	401	433	465	497	q	113
R	82	274	306	338	370	402	434	466	498	r	114
S	83	275	307	339	371	403	435	467	499	s	115
T	84	276	308	340	372	404	436	468	500	t	116
U	85	277	309	341	373	405	437	469	501	u	117
V	86	278	310	342	374	406	438	470	502	v	118
W	87	279	311	343	375	407	439	471	503	w	119
X	88	280	312	344	376	408	440	472	504	x	120
Y	89	281	313	345	377	409	441	473	505	y	121
Z	90	282	314	346	378	410	442	474	506	z	122
[	91	283	315	347	379	411	443	475	507	{	123
\	92	284	316	348	380	412	444	476	508	|	124
]	93	285	317	349	381	413	445	477	509	}	125
^	94	286	318	350	382	414	446	478	510	~	126
_	95	287	319	351	383	415	447	479	511	RUBOUT (DEL)	127
		40	41	42	43	44	45	46	47		
		(	)	*	+	,	-	.	/		

High Order X & Y

Fig. 3-4. Coordinate Conversion Chart Part 2 of 4. (For conversion instructions see Fig. 3-2.)

Low Order X										Low Order Y	
ASCII	DEC	X or Y Coordinate								ASCII	DEC.
@	64	512	544	576	608	640	672	704	736	`	96
A	65	513	545	577	609	641	673	705	737	a	97
B	66	514	546	578	610	642	674	706	738	b	98
C	67	515	547	579	611	643	675	707	739	c	99
D	68	516	548	580	612	644	676	708	740	d	100
E	69	517	549	581	613	645	677	709	741	e	101
F	70	518	550	582	614	646	678	710	742	f	102
G	71	519	551	583	615	647	679	711	743	g	103
H	72	520	552	584	616	648	680	712	744	h	104
I	73	521	553	585	617	649	681	713	745	i	105
J	74	522	554	586	618	650	682	714	746	j	106
K	75	523	555	587	619	651	683	715	747	k	107
L	76	524	556	588	620	652	684	716	748	l	108
M	77	525	557	589	621	653	685	717	749	m	109
N	78	526	558	590	622	654	686	718	750	n	110
O	79	527	559	591	623	655	687	719	751	o	111
P	80	528	560	592	624	656	688	720	752	p	112
Q	81	529	561	593	625	657	689	721	753	q	113
R	82	530	562	594	626	658	690	722	754	r	114
S	83	531	563	595	627	659	691	723	755	s	115
T	84	532	564	596	628	660	692	724	756	t	116
U	85	533	565	597	629	661	693	725	757	u	117
V	86	534	566	598	630	662	694	726	758	v	118
W	87	535	567	599	631	663	695	727	759	w	119
X	88	536	568	600	632	664	696	728	760	x	120
Y	89	537	569	601	633	665	697	729	761	y	121
Z	90	538	570	602	634	666	698	730	762	z	122
[	91	539	571	603	635	667	699	731	763	{	123
\	92	540	572	604	636	668	700	732	764	|	124
]	93	541	573	605	637	779	701	733	765	}	125
^	94	542	574	606	638	670	702	734	766	~	126
_	95	543	575	607	639	671	703	735	767	RUBOUT (DEL)	127
		48	49	50	51	52	53	54	55		
		0	1	2	3	4	5	6	7		
		High Order X & Y									

Fig. 3-5. Coordinate Conversion Chart Part 3 of 4. (For conversion instructions see Fig. 3-2.)

Low Order X										Low Order Y	
ASCII	DEC.	X or Y Coordinate								ASCII	DEC.
@	64	768	800	832	864	896	928	960	992	`	96
A	65	769	801	833	865	897	929	961	993	a	97
B	66	770	802	834	866	898	930	962	994	b	98
C	67	771	803	835	867	899	931	963	995	c	99
D	68	772	804	836	868	900	932	964	996	d	100
E	69	773	805	837	869	901	933	965	997	e	101
F	70	774	806	838	870	902	934	966	998	f	102
G	71	775	807	839	871	903	935	967	999	g	103
H	72	776	808	840	872	904	936	968	1000	h	104
I	73	777	809	841	873	905	937	969	1001	i	105
J	74	778	810	842	874	906	938	970	1002	j	106
K	75	779	811	843	875	907	939	971	1003	k	107
L	76	780	812	844	876	908	940	972	1004	l	108
M	77	781	813	845	877	909	941	973	1005	m	109
N	78	782	814	846	878	910	942	974	1006	n	110
O	79	783	815	847	879	911	943	975	1007	o	111
P	80	784	816	848	880	912	944	976	1008	p	112
Q	81	785	817	849	881	913	945	977	1009	q	113
R	82	786	818	850	882	914	946	978	1010	r	114
S	83	787	819	851	883	915	947	979	1011	s	115
T	84	788	820	852	884	916	948	980	1012	t	116
U	85	789	821	853	885	917	949	981	1013	u	117
V	86	790	822	854	886	918	950	982	1014	v	118
W	87	791	823	855	887	919	951	983	1015	w	119
X	88	792	824	856	888	920	952	984	1016	x	120
Y	89	793	825	857	889	921	953	985	1017	y	121
Z	90	794	826	858	890	922	954	986	1018	z	122
[	91	795	827	859	891	923	955	987	1019	{	123
\	92	796	828	860	892	924	956	988	1020	|	124
]	93	797	829	861	893	925	957	989	1021	}	125
^	94	798	830	862	894	926	958	990	1022	~	126
_	95	799	831	863	895	927	959	991	1023	RUBOUT (DEL)	127
		56	57	58	59	60	61	62	63		
		8	9	:	;	<	=	>	?		

High Order X & Y

Fig. 3-6. Coordinate Conversion Chart Part 4 of 4. (For conversion instructions see Fig. 3-2.)

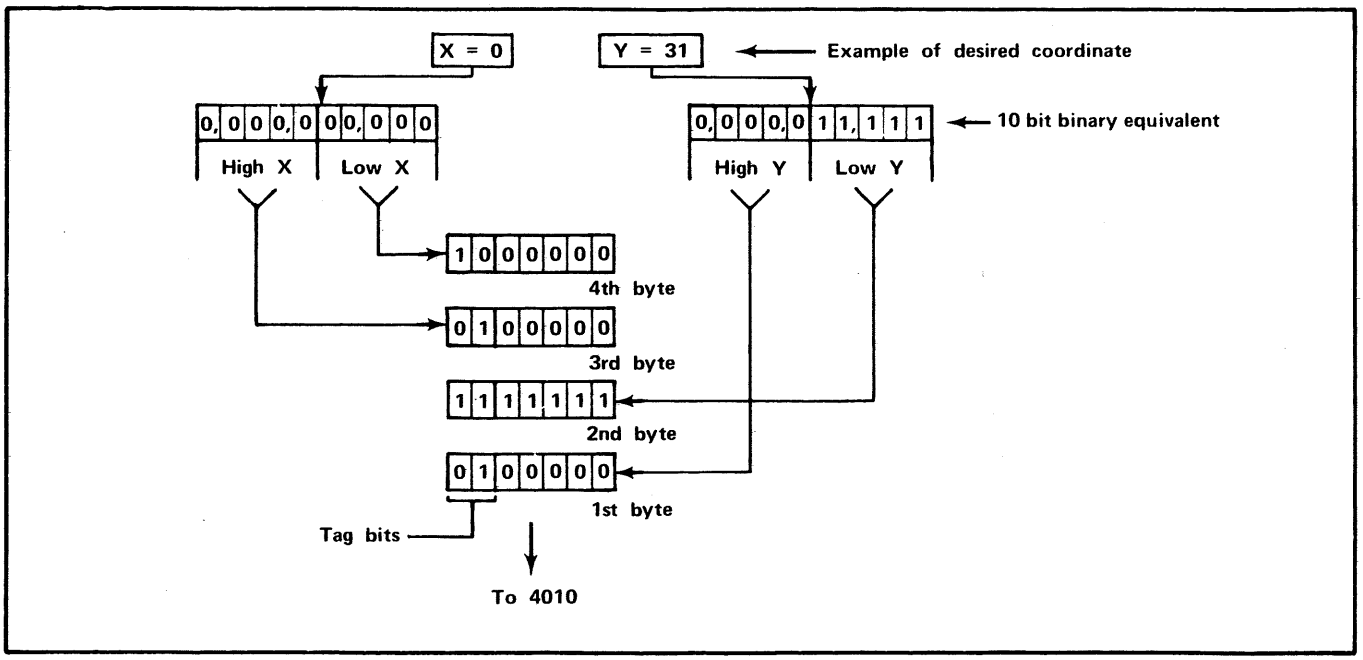


Fig. 3-7. Method of computing 4 byte data from a desired display coordinate.

Fig. 3-7 shows a method of computing the 4 bytes using the example of the desired coordinate of X = 0 and Y = 31. The numbers are converted to a 10-bit binary equivalent. Each is divided into High and Low 5 bits. The bytes are assembled as shown with the two tag bits added. This method is used where computer sub-routines are set up to do this conversion. After a GS and the initial 4 bytes have been sent to the 4010, additional bytes that do not change (execpt for the Low X byte) need not be sent; however, Low Y bytes must be sent if High X byte has been changed. The Low X byte must be sent each time to cause the point or vector to be drawn.

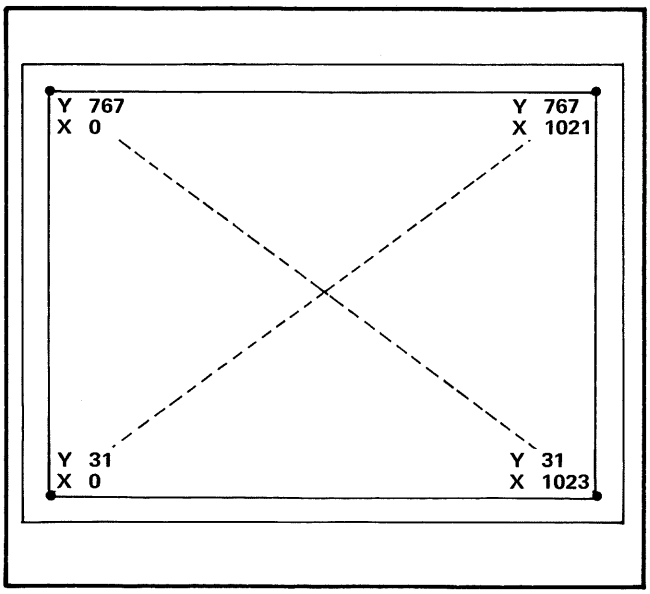


Fig. 3-8. Manual entry graphic plot.

Manual entry for graphic plotting normally can not be accomplished as the only characters that can be sent from the keyboard for the Low order Y are RUBOUT and ALT MODE (closing brace). However, the following procedure can be used for a checkout of the graphic plot mode for the plot as shown in Fig. 3-8. Note that the characters that are double underlined in the procedure 4 through 8, need not be sent.

1. Place the LOCAL LINE switch in the LOCAL position.

2. Turn 4010 POWER ON and after warmup press the PAGE key.

3. Enter the Graphic Plot mode with GS (CTRL SHIFT M).

4. Enter Space RUBOUT Space @ (Y = 31 and X = 0)

5. Enter 7 RUBOUT Space @ (Y = 767 and X = 0)

6. Enter 7 RUBOUT ? – (Y = 31 and X = 1023)

7. Enter Space RUBOUT ? – (Y = 31 and X = 1023)

8. Enter Space RUBOUT Space @ (Y = 31 and X = 0)

The diagonal vectors can be drawn by using the same characters.

When plotting is finished, return the 4010 to Alpha mode (US or CR control character) to allow the change into the "Hold mode". This prevents a residual image, or possible screen damage.

Graphic Input (Gin)

Using software, the computer can request the following graphic input information:

1. The Alpha cursor coordinate location.

2. Cross-hair cursor intersection coordinate location.

(A) Enables the Cross-hair cursor, and receives the present Cross-hair location.

(B) Enables the Cross-hair cursor and waits for the operator to change the Cross-hair controls to the desired intersection point. When the operator strikes a keyboard character, the character and the coordinate location are sent to the computer.

Fig. 3-9 shows the format to the computer in response to an ESC, ENQ. The 4010 Status byte 1

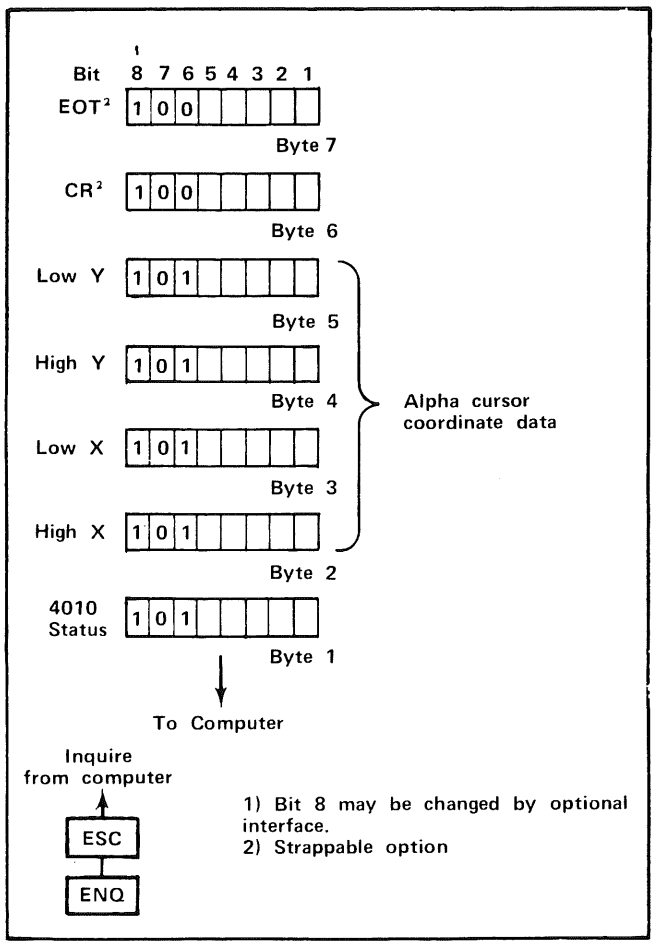


Fig. 3-9. 4010 response from ENQ, ESC from the computer. (Blank bits shown depend upon data information).

includes information about some of the signal lines in the 4010 to aid the programmer if required. Information of these status bits are as follows:

Bit	Line Name	Logic	Information
5	HCU	0	Means that the Hard Copy Unit is in working order ready to accept a copy request.
4	NOLI	0	Means that the linear interpolation is off.
3	GRAPH	0	Means that the 4010 is in a Graphic mode.
2	Margin	1	Means that the 4010 is at Margin 1.

Bit	Line Name	Logic	Information
1	AUX-SENSE	0	Indicates activation of the auxiliary device if attached.

Byte 2 through 5 contains the Alpha cursor coordinate data.

Byte 6 and byte 7 may be sent depending upon the setting of the Graphic Input terminator wired plug, see "Strappable Options".

Fig. 3-10 shows the format to the computer in response to the inquiry shown which consists of ESC, SUB, a 20 ms delay and ESC, ENQ. Byte 1 through 4 contains the Cross-hair cursor coordinate data. Byte 5 and 6 may be sent depending upon the setting of the Graphic Input terminator wired plug; see "Strappable Options".

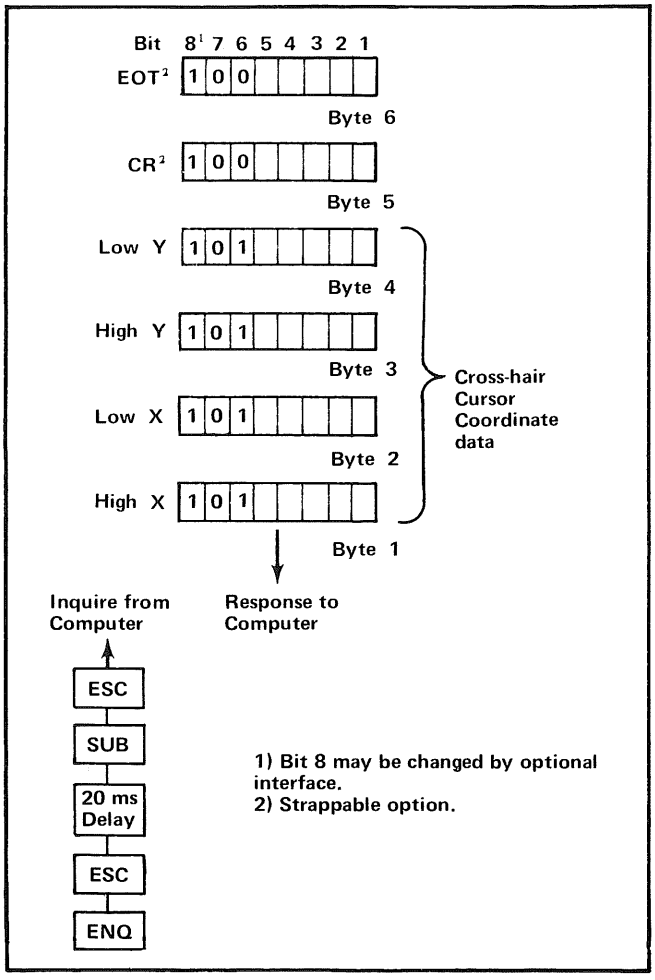


Fig. 3-10. 4010 response to inquiry (as shown) from the computer.

Fig. 3-11 shows the format to the computer in response to a computer command and operator control. First, an inquiry from the computer of ESC then SUB, which enables the Cross-hair cursor; Second, the Operator set up the Cross-hair controls to his desired position and strikes a printing key which initiates the response to the computer.

Conversion from the Graphic Input bytes (High X, Low X, High Y, Low Y of Figures 3-9, 10 and

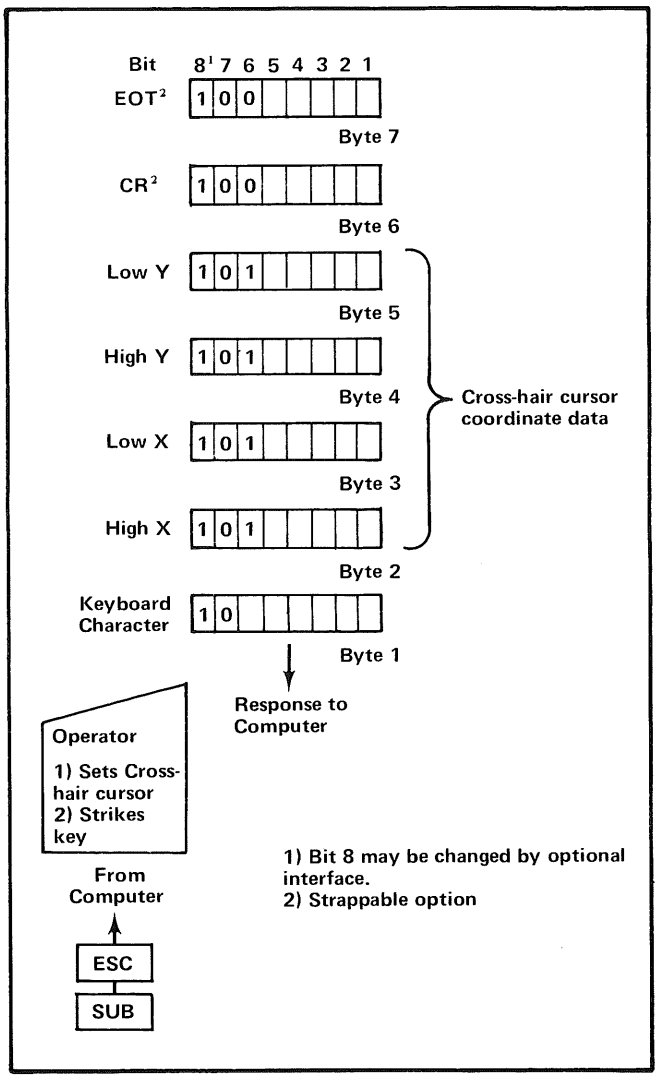


Fig. 3-11. 4010 response to computer command and operator control.

11) to numerical coordinates is a straight-forward operation. Ignore the parity bit 8 for this conversion. Note that 32 is deducted from each byte.

X coordinate = 32 times (High X –32) plus (Low X –32)

Y coordinate = 32 times (High Y –32) plus (Low Y –32)

Do not turn on the Cross-hair by striking the control character ESC, SUB from the keyboard when on line operating mode, as it may cause invalid coordinate information.

The 4010 does not display the characters sent to the computer when the cross-hair cursor is on, regardless of the placement of the Local Echo wired plug ("Strappable Options", Table 3-3).

Hard Copy Mode (4010-1)

In the Hard Copy Mode, the 4010-1 supplies the signals necessary to the Hard Copy unit. The Hard Copy unit will then generate a permanent copy of the 4010-1 display.

All the operator is required to do to make a copy of a desired display is to press CTRL SHIFT K then CTRL W, or press the MAKE COPY switch on the 4010-1.

The hard copy cycle is initiated by receiving ASCII ESC, ETB from the computer.

ASCII CODE FUNCTIONS

The ASCII Code Functions chart (see Fig. 3-12) is shown in binary with bits one to seven for each character. The chart shows the decimal equivalent for each character in each character's square. The two columns marked Control contain the ASCII abbreviations of the control characters. The groups of characters used for specific graphic functions are marked over their columns, but all six columns are used for Graphic Plotting.

CONTROL CHARACTERS

Control characters which will be recognized by the terminal are listed in Control Character information Tables 3-1 and 3-2.

STRAPPABLE OPTIONS

The features of the 4010/4010-1 can be changed through placement of wired plugs as hown in the Choice column of Table 3-3. The wired plugs for these options are located on circuit cards in the Pedestal section, and are available by removing the front cover.

CAUTION

Disconnect the Power from the Terminal while the front cover is removed.

See Fig. 3-13 for the location of the wired plug options on the circuit cards. Fig. 3-13 also shows the normal location of the circuit cards in the Pedestal, although the circuit cards could be installed in a different order without affecting the operation of the Terminal.

ASCII CODE FUNCTIONS

BITS B_7 B_6 B_5 / B_4 B_3 B_2 B_1	0 0 0	0 0 1	0 1 0	0 1 1	1 0 0	1 0 1	1 1 0	1 1 1
	CONTROL		HIGH X & Y GRAPHIC INPUT		LOW X		LOW Y	
0 0 0 0	NUL 0	DLE 16	SP 32	0 48	@ 64	P 80	` 96	p 112
0 0 0 1	SOH 1	DC1 17	! 33	1 49	A 65	Q 81	a 97	q 113
0 0 1 0	STX 2	DC2 18	" 34	2 50	B 66	R 82	b 98	r 114
0 0 1 1	ETX 3	DC3 19	# 35	3 51	C 67	S 83	c 99	s 115
0 1 0 0	EOT 4	DC4 20	$ 36	4 52	D 68	T 84	d 100	t 116
0 1 0 1	ENQ 5	NAK 21	% 37	5 53	E 69	U 85	e 101	u 117
0 1 1 0	ACK 6	SYN 22	& 38	6 54	F 70	V 86	f 102	v 118
0 1 1 1	BEL 7 BELL	ETB 23	' 39	7 55	G 71	W 87	g 103	w 119
1 0 0 0	BS 8 BACK SPACE	CAN 24	(40	8 56	H 72	X 88	h 104	x 120
1 0 0 1	HT 9	EM 25	) 41	9 57	I 73	Y 89	i 105	y 121
1 0 1 0	LF 10 LINE FEED	SUB 26	* 42	: 58	J 74	Z 90	j 106	z 122
1 0 1 1	VT 11	ESC 27	+ 43	; 59	K 75	[91	k 107	{ 123
1 1 0 0	FF 12	FS 28	, 44	< 60	L 76	\ 92	l 108	| 124
1 1 0 1	CR 13 RETURN	GS 29	- 45	= 61	M 77	] 93	m 109	} 125
1 1 1 0	SO 14	RS 30	. 46	> 62	N 78	^ 94	n 110	~ 126
1 1 1 1	SI 15	US 31	/ 47	? 63	O 79	_ 95	o 111	127 RUBOUT (DEL)

Fig. 3-12. ASCII Code Function Chart.

TABLE 3-1

SINGLE-CONTROL CHARACTER INFORMATION

ASCII Code			Keyboard Keys	4010 Function
Abbreviation	Decimal	Binary		
EOT	4	000 0100	CTRL D	End of Transmission. May be sent by 4010 as part of Graphic Input Sequence.
BEL (Bell)	7	000 0111	CTRL G	Tone from speaker
BS (Backspace)	8	000 1000	CTRL H	Moves 1 space left (14 points).
HT (Horizontal)	9	000 1001	CTRL I	Moves 1 space right (14 points).
LF	10	000 1010	CTRL J	Line Feed (22 points).
VT (Vertical tab)	11	000 1011	CTRL K	Moves 1 line up (22 points).
CR	13	000 1101	CTRL M	Carriage Return.
SO	14	000 1110	CTRL N	[1] Use alternate type characters.
SI	15	000 1111	CTRL O	[1] Use normal type characters.
ESC	27	001 1011	CTRL Shift K	First Control Character of a two-control character sequence, see Table 3-2.
GS	29	001 1101	CTRL Shift M	Sets Terminal in Graphic Mode.
US	31	001 1111	CTRL Shift O	Changes Terminal to Alpha Mode.

[1] Optional equipment required.

TABLE 3-2

DUAL-CONTROL CHARACTER INFORMATION

ASCII Code			Keyboard Keys	4010 Function
Abbreviation	Decimal	Binary	(Enter in sequence)	
ESC	27	001 1011	CTRL Shift K	
ENQ (Enquiry)	5	000 0101	CTRL E	a. ESC, ENQ sent by computer; Terminal returns status data and position bits. b. ESC, SUB, a 20 millisecond delay, then ESC, ENQ sent by computer; Terminal returns position of crosshair cursor. c. Note: ESC, SUB sent by Computer; then strike any keyboard character, the Terminal returns character and position of cross-hair cursor.
ESC	27	001 1011	CTRL Shift K	[1] Make Copy (4010-1)
ETB	23	001 0111	CTRL W	
ESC	27	001 1011	CTRL Shift K	Starts Cross-hair Cursor
SUB	26	001 1010	CTRL Z	
ESC	27	001 1011	CTRL Shift K	Erases Screen, returns to Alpha
FF	12	000 1100	CTRL L	Goes Home (Position 0, 767)

[1] Optional equipment required.

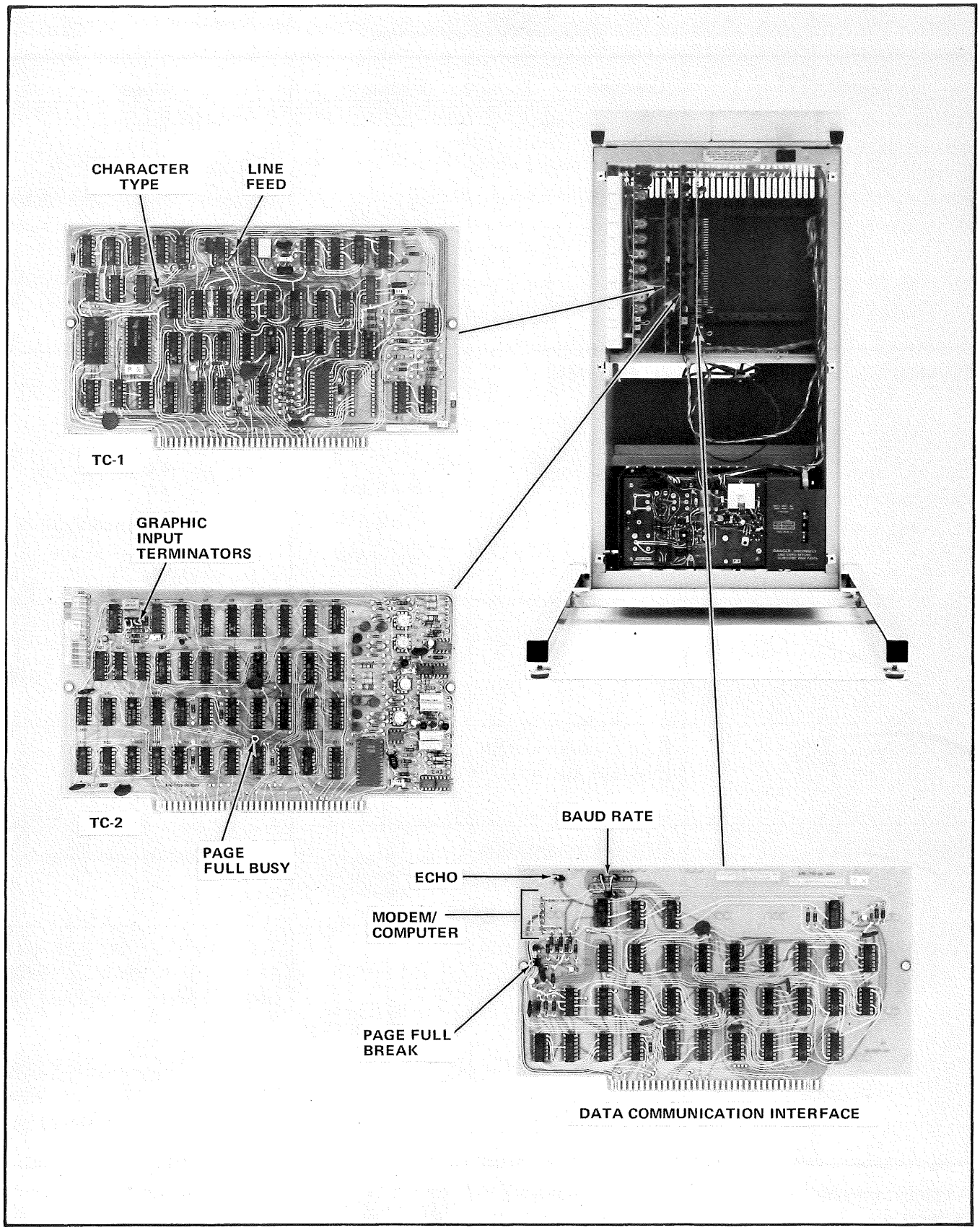
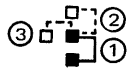
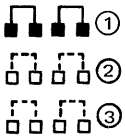
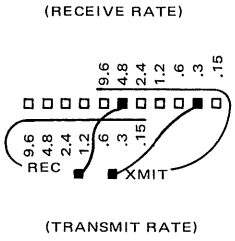
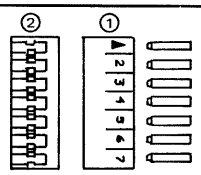


Fig. 3-13. Normal location of the plug-in cards in the 4010 are shown with the location of the Strappable options. Additional Strappable Option information is given in Table 3-3.

TABLE 3-3
STRAPPABLE OPTIONS

Feature	Location	Choice	Change
Character type (if alternate character memory is installed)	TC-1, 2nd row		1. Normal characters 2. Alternate or normal characters with switch 2 (on front panel). 3. Alternate or normal characters with SO or SI control characters.
Linefeed	TC-1 top row		1. Linefeed only 2. CR with Linefeed
Graphic Input Terminators	TC-2, top row		1. CR, and EOT (CTRL D) 2. CR only (Normal Position) 3. No CR, No EOT
Page Full Busy	TC-2, 4th row		1. Out 2. In (Makes 4010 Busy) (Normal Position)
Local Echo	Data Communication Interface, top row		1. In 2. Out
Page Full Break	Data Communication Interface, 2nd row		1. Out (Normal Position) 2. In
Baud Rate	Data Communication Interface, top row		1. R (Receive) 150, 300, 600, 1200, 2400, 4800, or 9600 baud. (Shown connected for 300 baud. 2. T (Transmit) 150, 300, 600, 1200, 2400, 4800, or 9600 baud. (Shown connected for 300 baud.)
Modem/Computer Connections	Data Communications Interface, left side (7 pin output connector)		1. To computer direct 2. To Modem (turn the cable plug over). (Normal Position).

SECTION 4

ACCESSORIES AND ADDENDUM

Introduction

This section of the manual is reserved for additional operating information and changes. Additional operating information may be required by the use of your accessories and optional interfaces.

SECTION 5
APPENDIX

INSTALLATION

General

The 4010 is built in two main sections. The pedestal section provides support for the display section, and contains the power supply, control circuits, and any optional circuits. The display section contains the keyboard, the display storage CRT, and related circuits.

Desk-Top Operation

With some installations, it may be desirable to operate the 4010 display section on a desk or table top.

The display section may be easily detached from the pedestal section and used for desk-top operation up to four feet away. However, the pedestal section should remain in its upright position, and should have an air space at the bottom as shown (see Fig. 5-1), for proper cooling.

To remove the display section from the pedestal section for desk-top operation proceed as follows:

1. Remove the four phillips head screws that hold the display section to the pedestal.

2. Carefully push the display section back until its safety hold-down lip is free from the pedestal top.

3. Lift the display section up and away from the pedestal, guiding the extender cable as you place the display section at the desired location.

4. To re-install the display section, use the following mounting procedure.

Display Mounting Procedure

Two people are required to mount the display unit on the pedestal, as follows (see Fig. 5-2):

1. Lift the display unit over the pedestal, inserting the cable straight down into the front of the cable trough. When the cable hits bottom, double the remaining cable back and forth into the trough.

2. Tilt the back of the display unit down and place its hold-down lip (underneath, near back) under the pedestal top (see insert in Fig. 5-2).

3. Lower the front of the unit in place. Then align the mounting holes by sliding the display forward.

4. Start the four screws through the pedestal top into the display unit. Then tighten the four screws.

CAUTION

The display unit center of gravity is slightly forward of the center of the pedestal when properly positioned. Support the display unit at all times until at least one securing screw is well started.

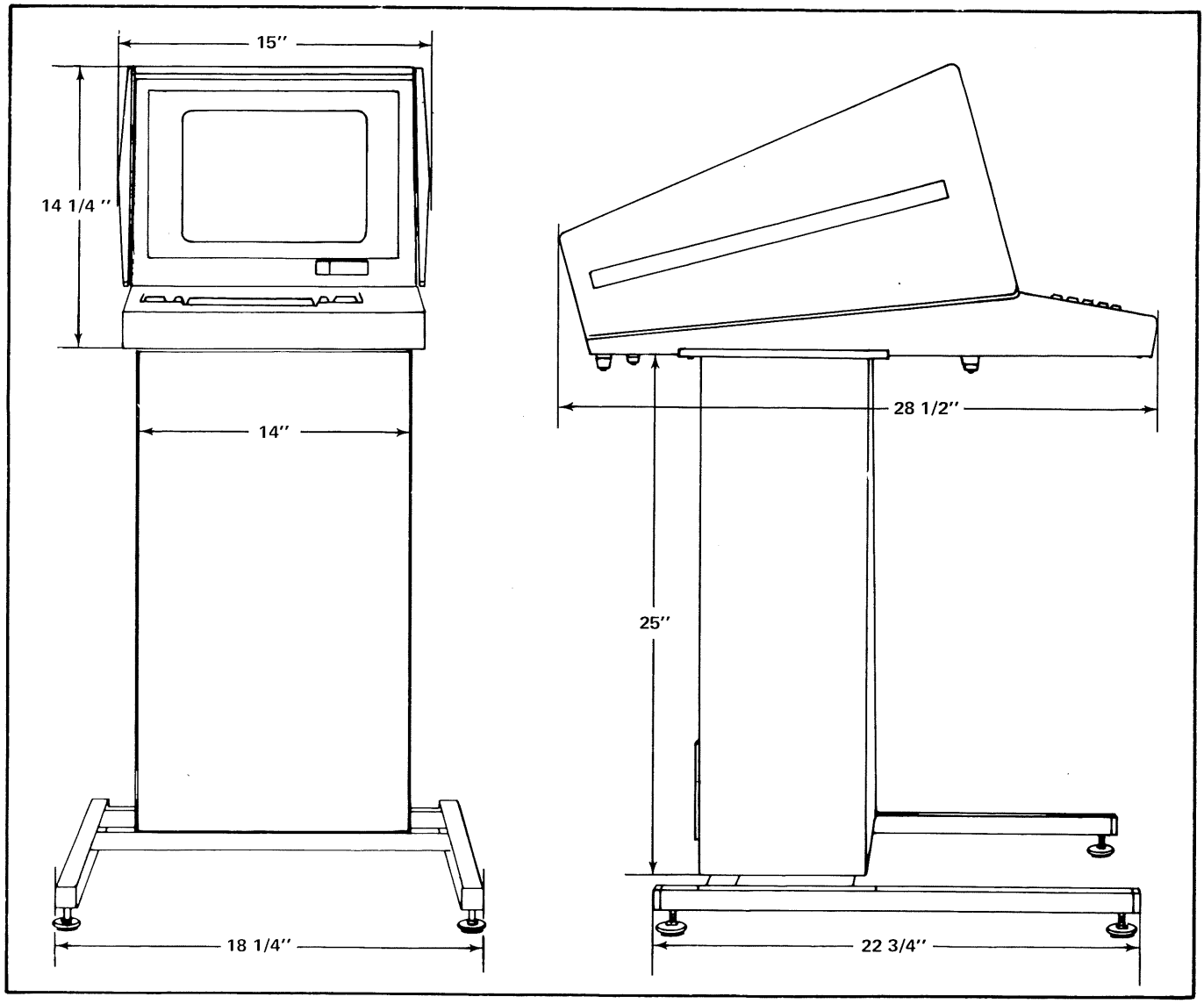


Fig. 5-1. Overall Dimensions.

Safety Considerations

The instrument is intended to be operated from a single-phase power source which has one of its current-carrying conductors (the neutral conductor) at ground (earth) potential. Operation from other power sources where both current-carrying conductors are live with respect to ground (such as phase-to-phase on a multi-phase system, or across the legs on a 117-234 V single-phase three-wire system) is not recommended, as only the line conductor has over-current (fuse) protection within the instrument.

The instrument is provided with a three-wire power cord with a three-terminal polarized plug for connection to the power source. The grounding terminal of the plug is directly connected to the instrument frame as recommended by national and international safety codes. Color coding of cord conductors follows the National Electrical Code (ANSI C1-1968) which specifies Line, Black; Neutral, White; Safety Earth or Ground, Green with a yellow stripe (or solid green).

CAUTION

Disconnect the Power from the Terminal while the front cover is removed.

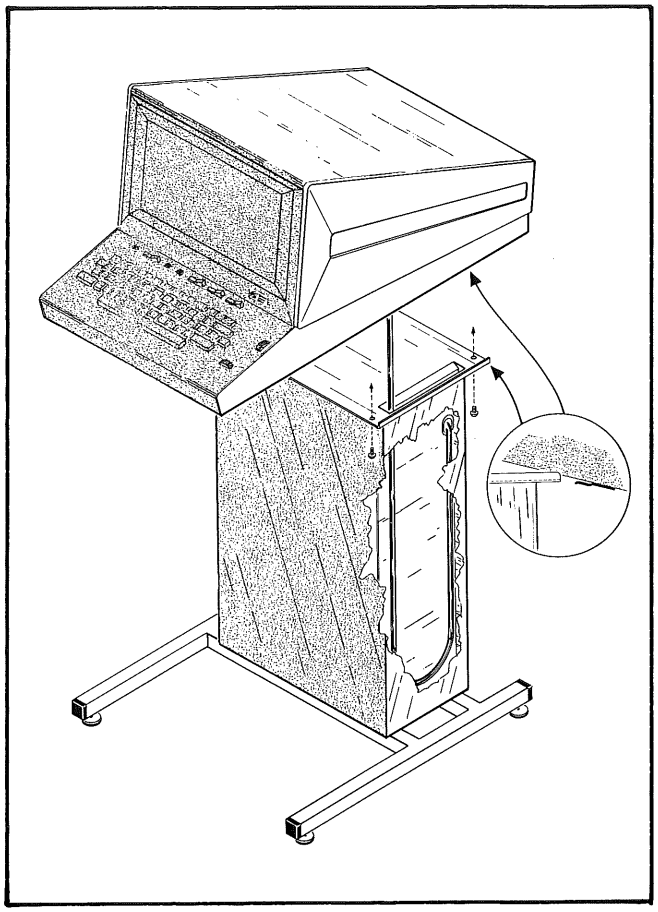


Fig. 5-2. Display mounting information.

If it is necessary to change the transformer terminal taps to conform to your AC input voltage range, remove the 4010 front cover by removing the screws around the edge of the cover. When you remove the cover, the line fuse comes out of its clip and is retained on the 4010 front cover. See Fig. 5-3. The transformer terminals are available by removing the two cover screws as shown in the Figure.

Fig. 5-4 shows the transformer terminals 1 through 8 with the line cord attached to terminals 1 and 4 (L1 and L2). By placing the proper jumpers to the terminals, AC input voltage ranges of 100, 110, 120, 200, 210, or 220, all ±10% can be used. Use the jumper arrangement table as shown in the Figure; for example, with 110 VAC, ±10% input voltage, jumper terminal 1 to 2 and 4 to 3 only.

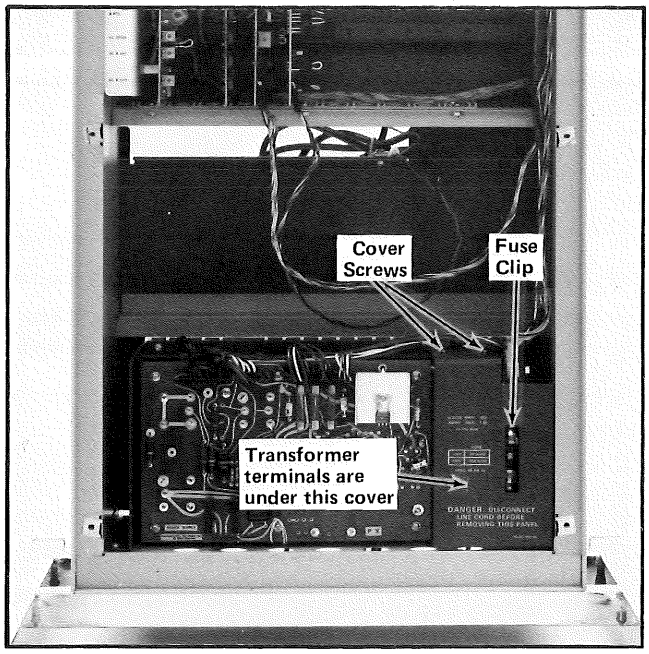


Fig. 5-3. Transformer terminals and fuse clip location. The fuse is removed with the instrument front cover.

ESTABLISHING COMPUTER CONNECTION

General

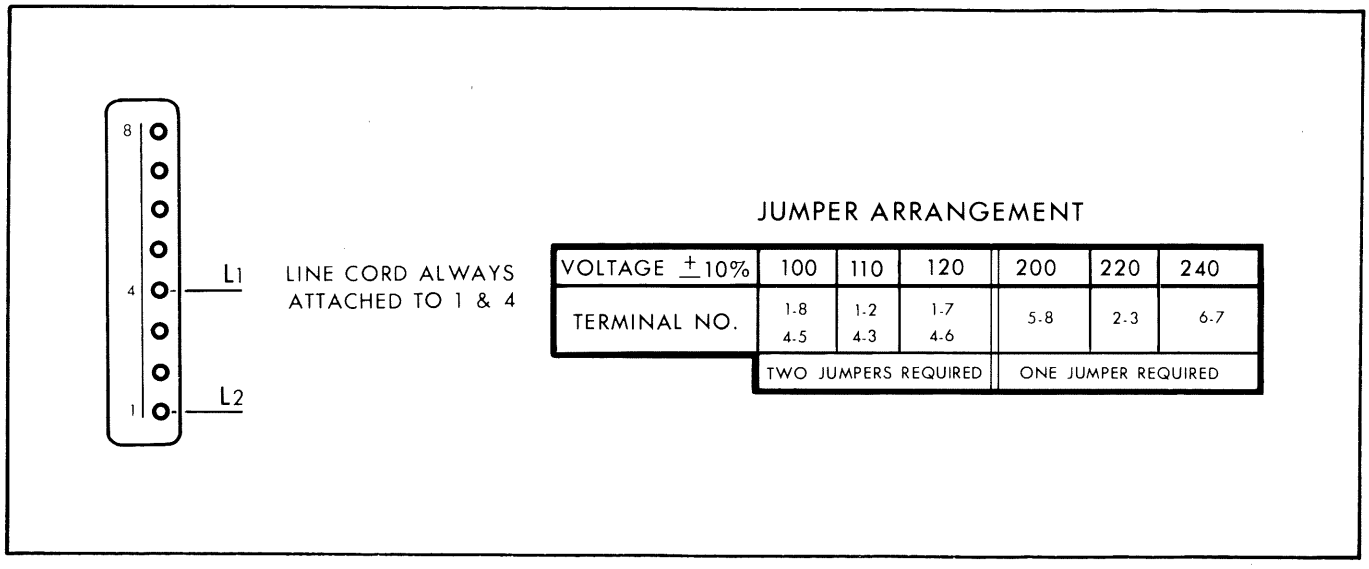
This procedure is given as an aid to establish the Terminal-computer communication link. There are two basic methods of connecting a 4010 Terminal. These are:

1. Direct Connection
2. Phone Line Connection

Direct Connection

A direct connection is used when the Terminal and the computer are located close to each other so a connection can be established without the use of modems.

1. Check on the proper setting of the internal baud straps, for the desired baud rate. Also check the Modem/Computer option connection. For information about these, see the "Strappable Options", page 3-11.



JUMPER ARRANGEMENT

VOLTAGE ±10%	100	110	120	200	220	240
TERMINAL NO.	1-8 4-5	1-2 4-3	1-7 4-6	5-8	2-3	6-7
	TWO JUMPERS REQUIRED			ONE JUMPER REQUIRED		

Fig. 5-4. Line Voltage terminals and jumper arrangement.

2. Make sure that the terminal is connected to the proper power using a three-terminal power plug for proper grounding. For other power requirements see the installation information in this section.

3. Make sure the 4010 Interface connector is connected to the computer line.

Phone Line Connection

A phone line connection can be made when the distance separating the terminal and the computer is too great to establish a direct connection (sometimes, the computer may be located thousands of miles from the Terminal). When this type of connection is used, additional equipment in the form of a modem is required. The telephone companies rent these modulators-demodulators (modems) like telephones and call them "data sets" (Western Union) or "Data-phone" (AT & T). Both ends of the telephone line, at the Terminal and the computer, require a modem. There are a number of specialized modems available; the type you have will depend on your specific needs. To establish the phone line connection, proceed as follows:

1. Check on the proper setting of the internal baud straps, for the desired baud rate. Also check the Modem/Computer option connection. For information about these, see the "Strappable Options", page 3-11.

2. Make sure that the Terminal is connected to the proper power using a three-terminal power plug for proper grounding. For other power requirements see the installation information in this section.

3. Make sure the 4010 Interface connector is connected to the modem (data set).

4. Put the LOCAL/LINE switch in the LINE position.

5. Turn the POWER switch to the ON position, and wait for the display screen to reach the "fully written" condition (the display will glow with a bright green tint). When this occurs, press the PAGE key to "normalize" the display.

6. Use your telephone, and dial the computer number. The modem at the computer end will respond by sending an audible tone to your telephone receiver. When this occurs, place the telephone head set on the cradle provided on your modem. (In case of a "data set" type modem, push the button marked DATA, and hang up the headset.)

7. As the details of the sign-on procedure will vary from one time sharing system to another, proceed with the sign-on that is required by the computer system called.

INTERFACING INFORMATION

Minibus Structure

The 4010 Computer Display Terminal is organized on a bus structure for data routing and control. A bus can be thought of as a piece of wire, along the length of which any number of connections can be made. When one end of the bus is connected to a signal source, that signal is available over the length of the bus. The term minibus is used to describe the series of short busses connecting each corresponding pin of three 72-pin connectors in the standard 4010. The two Terminal Control logic cards and the interface card will occupy the three available connectors in the standard 4010. Therefore, when considering the addition of optional TEKTRONIX accessories or customer designed accessories, it will be necessary to obtain the minibus extender (TEKTRONIX Part No. 670-1743-00) which adds five additional 72-pin connectors to the minibus.

The bus principle is widely used by manufacturers of mini-computers. It represents a significant advance in the design and manufacture of computer terminals. Some of the advantages of bus structuring are listed below:

1. Costly and complex intercard wiring is eliminated. The 4010 minibus is very simple, consisting of only 72 parallel lines.

2. Design updating is easily accomplished. If a redesign of a circuit card should involve using an additional line or two, in the 4010 it is only necessary to pick up the new line(s) with the new circuit card.

3. No card is fixed in its position on the minibus. Since all lines are available to all connectors no card has a particular slot into which it must go. Any circuit card in the 4010 will fit and work in any connector. The connectors are "keyed", however, so that the component side of the card is always to the right.

4. Maintenance is simplified. Complex wiring lists and diagrams are not required to keep track of data and control signals from card to card. With the 4010, only a diagram of one of the connectors is required. See Fig. 5-5.

5. Connecting external devices and accessories into the 4010 is greatly simplified. Again it is only necessary to look at a diagram of one connector and design the circuit card to pick up only those lines from the bus that are necessary for the operation of the circuit card.

The minibus structure of the 4010 allows great flexibility, which allows it to utilize a wide range of available options.

Interfacing Considerations

The 4010 offers a wide range of standard interfaces; however, some users will have unusual applications or prefer to design their own interfaces. Included in this section, for this purpose, is the 4010 connector diagram, line titles and description, and a basic timing diagram. Technical details and the source of these signals can be found in the 4010 Maintenance Manual (TEKTRONIX Part No. 070-1183-00). Conceptual descriptions of TEKTRONIX basic interfacing methods follow this section. While TEKTRONIX basic interfacing methods are designed for serial data transfers, parallel data transfers should be easily accomplished because of the bus structure of the 4010.

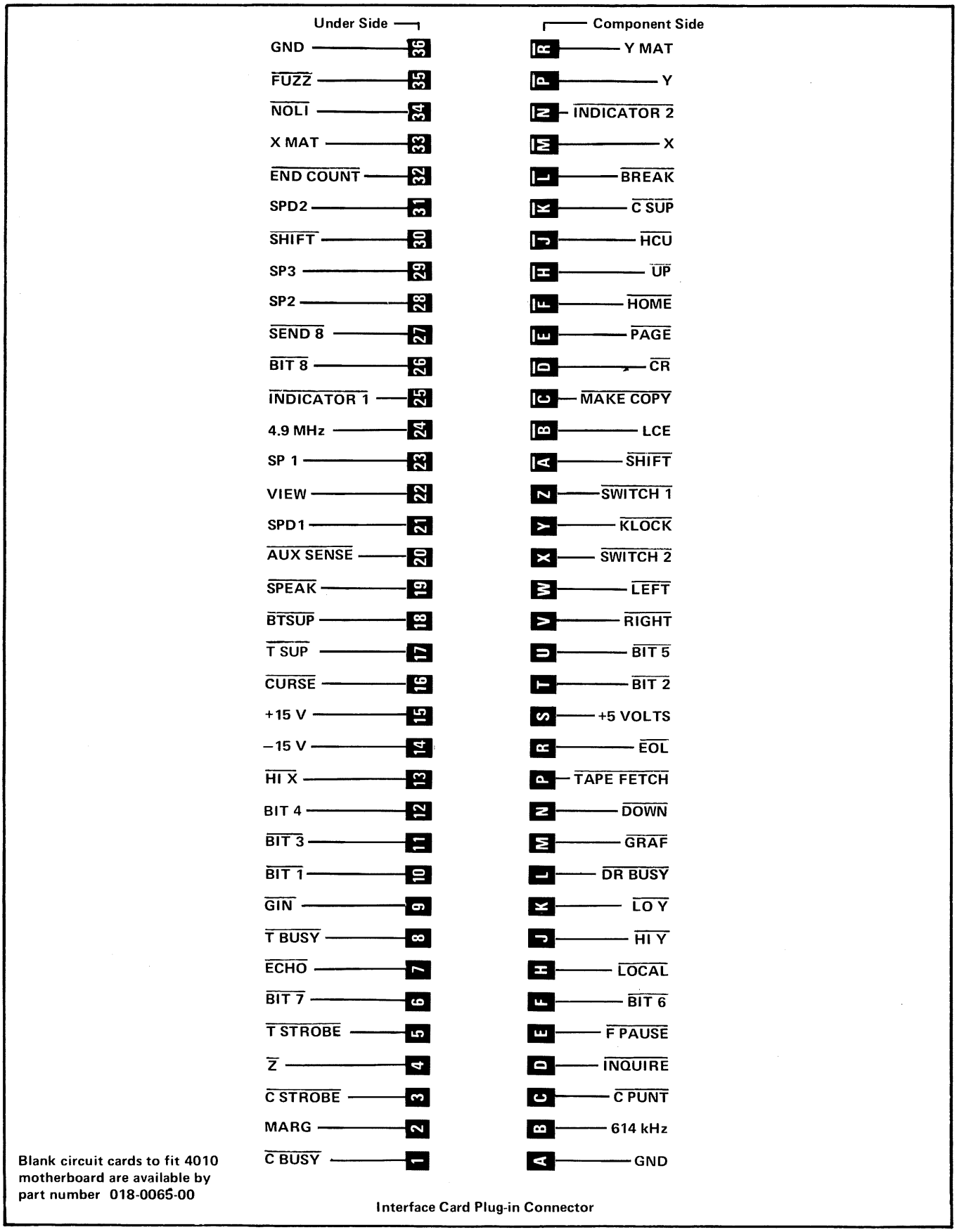


Fig. 5-5. Signal names and lines at the motherboard connector in the 4010.

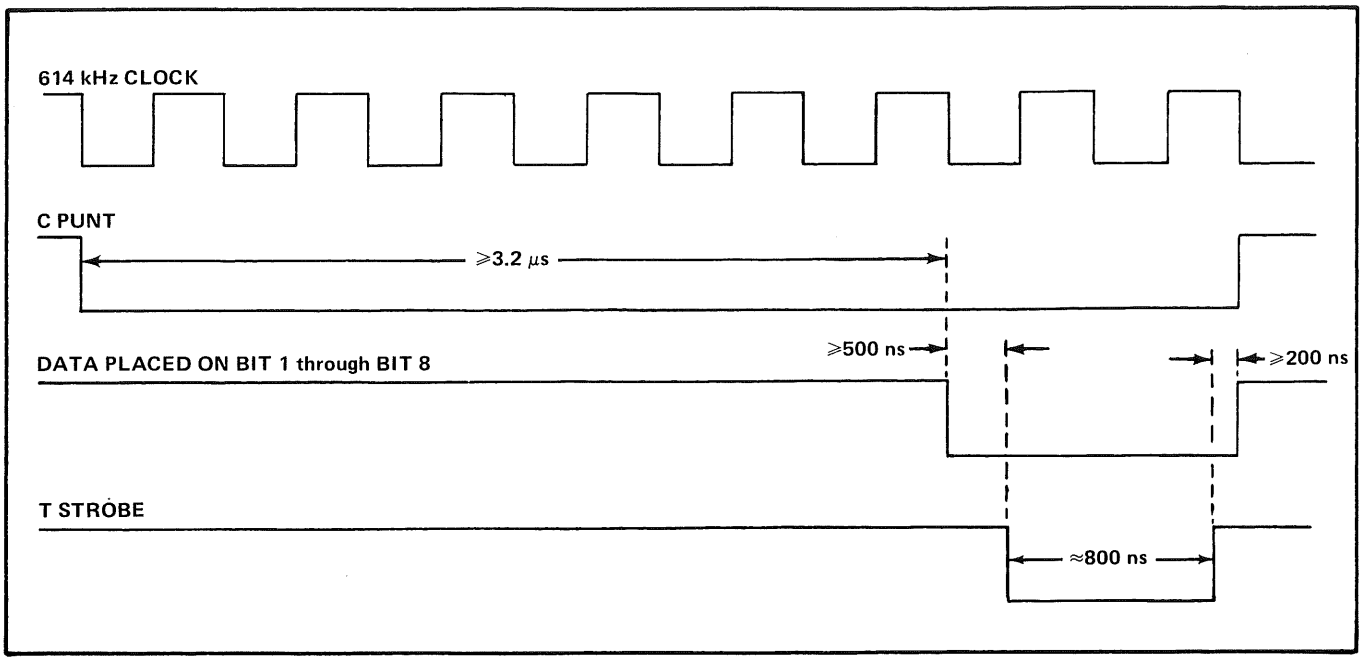


Fig. 5-6. Timing information.

A few lines will be necessary for all interfacing, and other lines can be added as necessary for refinement. (Refer to line titles list later in this section for more complete description and the timing diagram in Fig. 5-6). The necessary lines will be:

1. TSTROBE, CSTROBE—TSTROBE will have to be asserted for all transfers to the 4010, and CSTROBE will have to be asserted for all transfers to the external device.

2. CBUSY, TBUSY, CPUNT—These lines are used for "flagging" and proper interleaving of data transfers. Interleaving refers to timesharing the bus between data sources.

3. BIT 1—BIT 8—These are the data lines. BIT 1—BIT 7 are normally the 7-bit TTY subset (i.e. no lower case alphanumerics) of the ASCII code. BIT 8 will be always transmitted as a 1 when the Keyboard is used as the data source.

4. DRBUSY—Another "flagging" signal that indicates when a hard copy is being made, or the 4010 is erasing.

5. 614 kHz or 4.9 MHz—Clock signals used to time data transfers.

It is good practice to buffer or latch the data (BIT 1—BIT 8) from the bus onto the circuit card where it can be "remembered" while it is being processed. The actual data transfer can then be effected by the appropriate division of the 614 kHz or 4.9 MHz clock signal after being initiated by either TSTROBE or CSTROBE and the appropriate busy signal.

Line Names

The following is a description of the minibus line names and the explanation of their purpose and operation. Active states are given. A bar over the title shows that the active state is a low signal.

$\overline{\text{BIT 1}}$—$\overline{\text{BIT 8}}$ Data to and from the Terminal/computer. Normally the 7 bit TTY subset of the ASCII code.

$\overline{\text{SEND 8}}$ — Indicates data is to be sent as a full 8-bit byte (do not add parity).

$\overline{\text{CPUNT}}$ — Means data is about to be sent to the minibus by the computer (Interface). Must be sent at least 5 microseconds before data is placed on BIT 1–8 lines and must remain low until after the trailing edge of the strobe(s) associated with the transfer.

$\overline{\text{TSTROBE}}$ — Strobes data into the Terminal to be displayed on the screen, etc. 1.6 microsecond pulse synchronized to the 614 kHz clock.

$\overline{\text{CSTROBE}}$ — Strobes data to the computer. Pulse width 1.6 microseconds sync'd to the clock. Must not occur more than 2 microseconds after CPUNT goes low. $\overline{\text{TSTROBE}}$ may be asserted simultaneously (from the same source) to provide local copy to the Terminal.

$\overline{\text{TBUSY}}$ — Terminal is busy writing a character or vector, etc. $\overline{\text{TBUSY}}$ controls the timing of data transmitted to the Terminal. Upon receipt of a byte of data, the Terminal will assert $\overline{\text{TBUSY}}$ by the trailing edge of $\overline{\text{TSTROBE}}$ if that byte is to make the Terminal busy. No condition, with the exception of MARG, shall assert $\overline{\text{TBUSY}}$ except momentarily. (MARG can be patched out of $\overline{\text{TBUSY}}$.) The Terminal will, however, accept data if $\overline{\text{TBUSY}}$ is high or low although the results in that case are not defined. $\overline{\text{TBUSY}}$ does not inhibit transmission of data from the Keyboard to the computer.

$\overline{\text{CBUSY}}$ — Computer (Interface) is busy accepting a character. Controls the timing of coordinate data transmitted to the computer. A low on $\overline{\text{CBUSY}}$ will not inhibit the Keyboard, allowing Keyboard interrupts when $\overline{\text{CPUNT}}$ is not asserted. Interfaces which must lock out the Keyboard should do so with $\overline{\text{KLOCK}}$.

$\overline{\text{TSUP}}$ — Suppresses Terminal response to $\overline{\text{TSTROBE}}$. $\overline{\text{TSUP}}$ should be used by auxillary devices which need to blank the Terminal to incoming data, such as a paper tape punch when punching binary data. $\overline{\text{BTSUP}}$ should be asserted in response to $\overline{\text{CPUNT}}$ by devices (such as buffers used in error correction schemes) intended to intercept data on behalf of the Terminal. In such cases the assertion of $\overline{\text{BTSUP}}$ should be delayed 2 clock periods to avoid interference with copy of locally generated data.

$\overline{\text{BTSUP}}$ — Blanks the entire Terminal (including aux devices to data). A typical use is in a multi-drop system to suppress messages to other terminals. If the Keyboard is to be active while the Terminal is blanked to incoming data, $\overline{\text{BTSUP}}$ should be asserted only in response to $\overline{\text{CPUNT}}$, delayed two clock cycles from the beginning of $\overline{\text{CPUNT}}$.

LCE — (TC-1) Indicates last character sent to Terminal was ESC.

$\overline{\text{CSUP}}$ — Inhibits the Interface from accepting $\overline{\text{CSTROBE}}$. This signal is normally asserted by devices such as line buffers which need to intercept data destined for the computer.

$\overline{\text{KLOCK}}$ — Inhibits Keyboard. Normally held at a high level.

$\overline{\text{TAPEFETCH}}$ — A pulse or level provided by (typically) some small computer interfaces to cause a paper tape reader or analagous device to read data.

$\overline{\text{Z}}$ — Z axis information.

$\overline{\text{UP}}$
$\overline{\text{DOWN}}$
$\overline{\text{LEFT}}$
$\overline{\text{RIGHT}}$ — Counting pulses for X and Y Registers.

MARG — Indicates that the Terminal is at Margin 1. With a directly connected Interface this corresponds to Page Full. High active.

$\overline{\text{EOL}}$ — Indicates that the X Register is counting past the right margin. Used by the Automatic Carriage Return/Line Feed logic when in the Alpha Mode, $\overline{\text{EOL}}$ going active causes an automatic Carriage Return (CR)/Line Feed (LF) for function.

$\overline{\text{TOPEN}}$ — Disables Top-of-Page circuit allowing an increased number of lines. Not brought out to minibus except by straps. Activation of $\overline{\text{TOPEN}}$ would depend upon user requirements.

$\overline{\text{HOME}}$ — Master reset for all logic. Origin in Keyboard (Reset key) and TC-1 when power is initialized.

$\overline{\text{HIY}}$
$\overline{\text{LOY}}$
$\overline{\text{HIX}}$
$\overline{\text{LOXE}}$ — Used to load data into the Y and X Data Latches and ($\overline{\text{LOXE}}$) to draw vectors.

$\overline{\text{GRAF}}$ — Originates in TC-1. Asserting a low on $\overline{\text{GRAF}}$ will set the 4010 in Graphic Plot Mode.

$\overline{\text{NOLI}}$ — Suppresses Linear Interpolation vector drawing and timing circuitry on TC-1 and TC-2. Asserted by TC-1 when in Alpha Mode.

$\overline{\text{DRBUSY}}$ — If not during an ERASE cycle:

Asserted by the Hard Copy Unit to set up the display for hard copy readout. $\overline{\text{DRBUSY}}$ should be asserted before the trailing edge of $\overline{\text{MAKE COPY}}$ in order to hold the Terminal in BUSY during the scan.

If during an ERASE cycle:

Asserted by the display for the duration of the erase cycle, during which information may not be written on the screen.

$\overline{\text{HCU}}$ — Indicates that the Hard Copy Unit is capable of accepting a $\overline{\text{MAKE COPY}}$ request.

$\overline{\text{AUXSENSE}}$ — Status bit line reserved for auxiliary device(s). Note that $\overline{\text{HCU}}$ may also be used by aux device(s) if no Hard Copy Unit is connected and powered up. Disables Graphic Lookahead.

$\overline{\text{GIN}}$ — When originating in TC-2, indicates that the cross-hair cursor is on, or that coordinate information is being transmitted to the computer. Disables the Alpha Cursor, Top of Page, Margin Shifter and CR/LF circuits. Sets Echoplex Suppression. When asserted by TC-1 or options indicates that Terminal is in Graphic Plot Mode in order to insure that the Character Generator is disabled.

$\overline{\text{FPAUSE}}$ — Indicates that the X Register has folded over (passed 0) in the process of normal counting. Will go active with CR, FF, ETB, or RESET (HOME). Used to generate the pause required for proper operation of the Auto Linefeed circuit when used with a clocked interface. (Also used internally on TC-2 in Graphic Input Mode.)

$\overline{\text{ECHO}}$ — Directs input sources to assert $\overline{\text{TSTROBE}}$ as well as $\overline{\text{CSTROBE}}$ when sending data to the computer to provide a local copy on the screen of data sent to the computer.

$\overline{\text{LOCAL}}$ — Directs input sources to assert $\overline{\text{TSTROBE}}$ providing screen display in the absence of computer echo. The Interface(s) may also use this line. Originates in Keyboard switch.

$\overline{\text{SEND 8}}$ — Directs the Interface to accept full 8-bit binary data instead of providing its own data (parity) for the 8th bit. (The Keyboard does not provide an 8th bit of data.)

$\overline{\text{SWITCH 1}}$ $\overline{\text{SWITCH 2}}$ — Asserted by Keyboard switches SW1 and SW2. Their use is dependent upon user requirements or optional accessories.

$\overline{\text{FUZZ}}$ — Causes the display to defocus the writing beam in Vector Mode.

$\overline{\text{INQUIRE}}$ — Activated by ENQ Control Character. Sent by computer (after ESC Control Character) when requesting Terminal status.

$\overline{\text{CURSE}}$ — Activated by ESC and SUB Control Characters. Initiates Graphic Input Mode.

$\overline{\text{PAGE}}$ — Activated by FF Control Character, or Page key on Keyboard. Causes the display to erase the screen, reset to Alpha Mode and home the Alpha cursor. 1.6 microseconds wide minimum.

CR(H) — Causes X Register to set back to left side (Margin 0) of display.

LCE(H) — (See explanation for Escape).

$\overline{\text{MAKE COPY}}$ — Activated by ETB Control Character following ESC Control Character 866 μs width minimum. $\overline{\text{MAKE COPY}}$ can be activated by MAKE COPY switch on Keyboard.

$\overline{\text{INDICATOR 1}}$
$\overline{\text{INDICATOR 2}}$ — Turns on the light emitting diode indicators in the Keyboard area.

NOTE

The above control characters are patchable except CR. Pulse width = 1.6 microseconds for all Control Characters.

$\overline{\text{BREAK}}$ — Signal from the Keyboard to the Interface for computer signaling. Causes a pulse of 8 bit time duration to be sent to computer for interrupt purposes.

NOTE

On some Interfaces, BREAK may be pulsed up to +15 volts. Data signals may also be present on $\overline{\text{BREAK}}$.

SPEAK — Audio connection to the loudspeaker. Other terminal speaker is at 5 volts. Bypassed by a 0.01 microfarad capacitor.

XMAT
YMAT — Analog signals representing the writing beam location within the character matrix. Originate on TC-1.

X
Y — Analog deflection signals from TC-2 to display. −5 to +5 volts covers the screen. Positive signal corresponds to down and left deflection. 0 volts represents the physical center of the screen.

VIEW — Controls the flood guns in the CRT display unit. A high turns the guns on. As long as the Terminal is in GIN or HCU, and for about 90 seconds after the last information has been sent to the Terminal, TC-1 will cause VIEW to be high. Otherwise TC-1 places the display in "hold mode" by placing a 75 Hz signal with 12.5% duty factor on VIEW.

An optional device may place the display in non-store by pulling VIEW low.

614 kHz
4.9 MHz — Clock signals.

DATA COMMUNICATION INTERFACING

General

The purpose of a Data Communication Interface is to transfer data between the 4010 Terminal and a modem which further processes this data into signals that can be handled by telephone lines and equipment. A similar kind of interface has to be available in the computer also, so that its data is acceptable by the same telephone lines and equipment.

The signals that the phone lines and equipment can handle have been necessarily fixed by the telephone companies. In order to meet those requirements and allow various manufacturers of peripheral equipment interface to the phone lines, certain standards have been established. The

necessary voltage levels, logic levels and interconnection specifications are established by the EIA RS-232-C and CCITT, V24 specifications. Most manufacturers, including TEKTRONIX, that make equipment to be interfaced to the telephone lines follow the RS-232-C specification in the U.S., and CCITT, V24 in most of Europe. There are also other specifications which generally reflect the above specifications with exceptions but are not in wide use.

The functions that any Data Communication Interface has to provide then are:

1. Serialization—This will be associated with the Transmit Mode. The data to be transmitted is taken off the bus and into a register where the start and stop bits are added and possibly a parity bit is inserted in the bit 8 position. This data word will then be shifted out of the register bit by bit in synchronization with the appropriate transmitting clock signal as shown in Fig. 5-7A.

2. Deserialization—This will be associated with the Receive Mode. In this mode, the data is taken from the input line bit by bit into a 10 bit register, again synchronized with the appropriate clock. When the register has received all the bits, a strobe is generated which sends the 8 data bits to the bus simultaneously (in parallel). See Fig. 5-7B.

3. Voltage level conversion—This conversion has to be done to all data and control lines to match the requirements of the external devices. Therefore, the digital TTL levels (0 to +5 V) have to be converted to RS-232-C or CCITT, V24 levels and vice versa.

4. Timing—It is also necessary to match data transfer rates to existing facilities. This is usually accomplished in the Data Communication Interface by an appropriate frequency division of the host devices master clock. Typically data can be transferred at rates of 110, 300, 600, 1200, 2400, 4800, and 9600 bits per second. At data rates of greater than 1200 baud, however, the cost of modems and phone lines increases rapidly.

5. Control Signals—Modems generally require signals from the Terminal or computer so that their circuits are activated when the Terminal or computer is ready to be used. These control signals may be quite simple or complex, depending on the system requirements.

TABLE 5-1

J520 Output Connector (Data Communication Interface)

Pin No.	RS-232-C Circuit	CCITT Equiv.	Description
1	AA	101	Protective Ground (In 4010, chassis gnd at cable entrance)
2	BA	103	[1] Transmitted Data
3	BB	104	[1] Received Data
4	CA	105	Request to Send (on while 4010 is on)
5	CB	106	Clear to Send
7	AB	102	Signal Ground (Common Return)
8	CF	109	Received Line Signal Detector
20	CD	108.2	Data Terminal Ready (on while 4010 is on)

[1] Transmit and Receive Data lines are shown to communicate to a Modem. See Strappable Options information.

TEKTRONIX Data Communication Interface

This interface will come already installed in the standard 4010. It can be assumed that many users will be linked up to only one time-sharing service or computer, and will not be concerned with constantly changing data transfer rates or telephone service. While the Basic Data Communication Interface retains the flexibility to do this, the necessary switching has been left physically on the circuit card as patchable options. They will typically be set once to match a particular system and left alone.

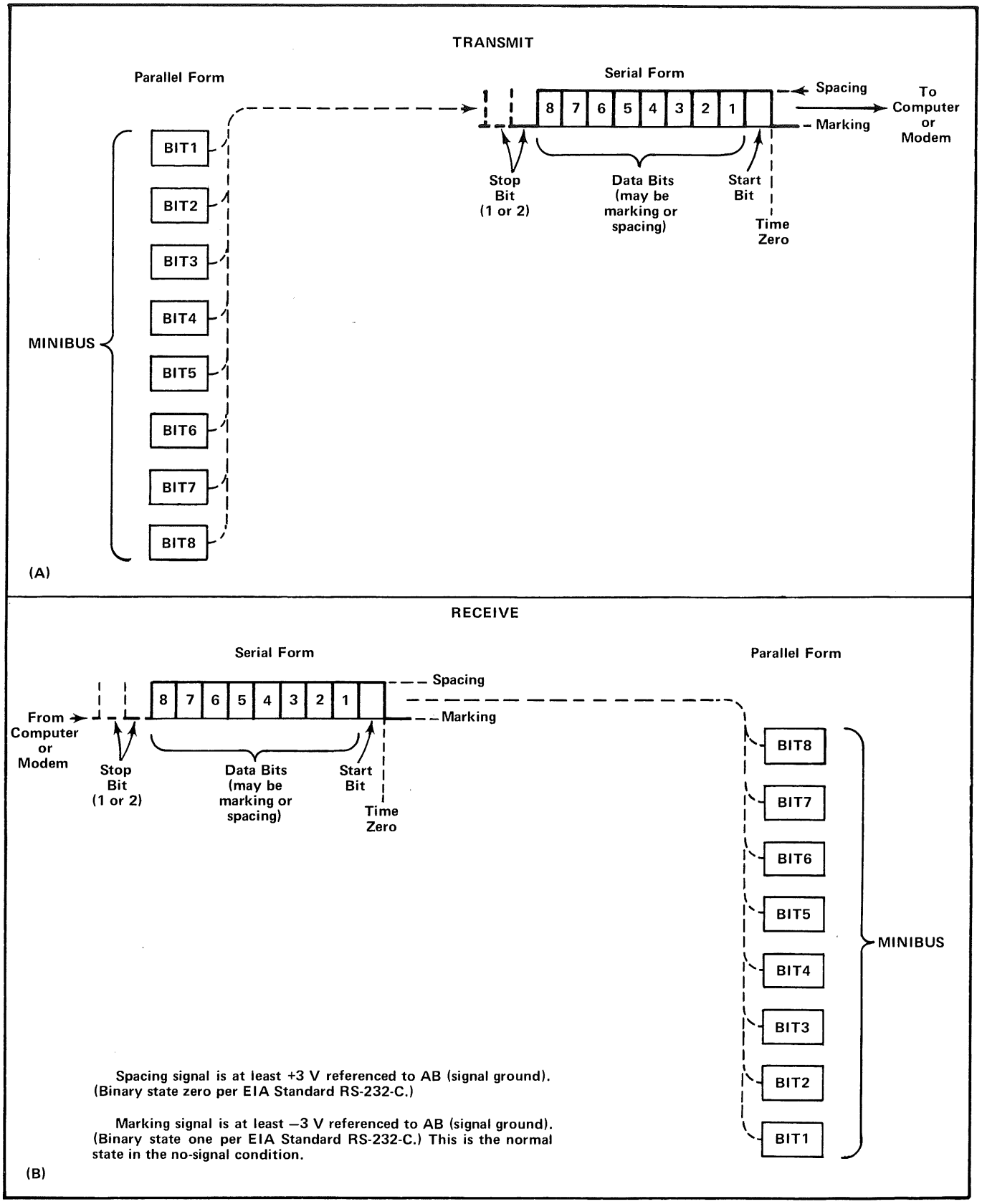


Fig. 5-7. Communication Interface "Transmit and Receive".

All the functions necessary for any Data Communication Interface i.e., Serialization, Deserialization, Level Conversion and Timing are physically located on one circuit card which is plugged into the 4010 minibus. The output signals are taken off the card through a 7 pin "harmonica" connector, and on out to a standard 25 pin modem inter-connecting plug. Only the control signals absolutely necessary for modem operation are available and no provision is made for true half duplex operation or supervisory channel hookup. This results in a subset of the RS-232-C specification and the lines used are shown in Table 5.1. Data format is serial asynchronous with 1 start bit, 7 data bits, parity and 1 stop bit. Parity is not checked on signals coming into the Data Communication Interface.

The strappable options are depicted in Table 3-3, and are located as shown in Fig. 3-13. Briefly described, they are as follows:

1. Local Echo—when "IN" provides a copy of the transmitted data on the display screen for those systems where the computer does not echo transmitted data back to the 4010. When "OUT" the 4010 relies on the computer to return transmitted data for a copy on the display screen.

2. Page Full Break—When "IN" a break signal will be sent to the computer automatically when alphanumeric data reaches the end of the 35th line. When "OUT" no break signal will be sent and 4010 will shift margin to the top and middle of the screen and continue printing data.

3. Baud Rate—Choice of data transfer rates independently selectable for transmit and receive. Transfer rates are 150, 300, 600, 1200, 2400, 4800, and 9600 baud.

4. (See NOTE) The 7 pin harmonica output connector can be "flipped" to allow for direct connection to a computer's RS-232-C interface without using modems.

NOTE

In those cases where it is desired to operate the 4010 within 50 feet or so of the computer, and the computer is equipped with an RS-232-C interface, the necessity for modems can be eliminated by a direct connection to the computer. This allows a very easy method of attaching to virtually any computer; but maximum transfer rate of a direct connection is limited.

Additional Interfaces

Two of the additional Interfaces, the Optional Data Communication and the Teletype Port Interface are briefly described in the following paragraphs. Consult the TEKTRONIX catalog, or contact your TEKTRONIX Applications/Engineer about additional Interface options and accessories for the 4010. Operating information for Interfaces (4010 options) will be included with each Interface. It is recommended that this operating information be placed in this manual in Section 4.

Optional Data Communication Interface. This interface is a further refinement of the Data Communication Interface, and has additional features for both convenience and for ease of operation. The Interface is designed to allow the Terminal to communicate with devices which transfer data serially in either full duplex or half duplex modes. It is designed to conform to EIA Standard RS-232-C. The Interface has its own internal clock; it can also be synchronized with external timing signals. A switch is installed at the rear of the 4010 to provide a quick change of strappable options such as baud rates. Switchable baud rates are provided from 110 to 9600, with two switch positions that may be set to any rate from 75 Hz to about 12 kHz.

Other features include, Normal Half Duplex, and two half duplex receiver blanking modes (1) where the turn around (direction of transmission) and blanking is changed by control characters; (2) Supervisory Mode, where the turn around and blanking is via supervisory channel.

Teletype Port Interface. This Interface is still another refinement of the Data Communication Interface, but is designed to operate directly with a computer (generally a mini-computer), and provide for the operation of a Teletype machine. The Interface contains the control circuits which drive the 4010 and the mini-computer's transmitting and receiving shift registers. A slight modification to the mini-computer's output circuitry is necessary. It is given along with the Interface.

The rear panel of the 4010 will contain a computer teletype port interfacing connector and a teletype port machine interfacing connector. A switch allows selection of the AUXiliary (the mini-computer), TTY (teletype machine), or OFF position (allowing the independent use of other Interfaces).

GLOSSARY OF TERMS

Address	On the display screen, the coded representation of a specific point.
Alpha Cursor	A non-storing, pulsating, 6 X 7 dot matrix that is used in the Alpha Mode to show the next writing position.
Alphanumeric	Pertains to letters of the alphabet, numerals and other symbols.
Alphanumeric Characters	A terms used to indicate alphabetic and numeric characters and special symbols.
Alpha Mode	One of the modes of operation used by the 4010. Only alphanumeric characters are displayed.
ASCII Code	American Standard Code for Information Inter-change. Established as an American standard by the American Standards Association.
Baud	A unit of data communication rate. Used to signify the speed of transmitted data or received data. One bit of data per second equals one baud.
Byte	A sequence of adjacent bits operated upon as a unit and usually shorter than a complete word.
Coordinate	A set of numbers used to specify a point on the screen.
Cross-hair Cursor	A non-storing cross-hair type display used in the Graphic Input Mode.
Data	Basic elements of information that can be processed and/or produced by a computer and the 4010.
Display Screen	The area of the CRT that displays information for viewing.
Cathode-ray Tube (CRT)	A television-like display tube used in display terminals. The visible image is created by a beam of electrons striking a luminescent phosphor.
Erase	To change the display electronic voltages in such a sequence and manner that all displayed information is cleared from the screen.

INDEX

	Page
A	
AC Input Voltage	5-3
Accessories & Addendum	4-1
Addressable Points	3-2
Alpha	3-1
Alpha Cursor	2-6, 2-7, 3-1
Alpha Mode	2-6, 3-1
Alpha Mode Checkout	2-7
ALT Mode	2-3
ASCII Code Functions	3-11
B	
Baud Rate	3-15, 3-16, 5-14
BREAK	2-3
C	
Character Type	3-1, 3-15, 3-16
Controls	2-1
Control Characters	3-11
Control Character Information, Single	3-13
Control Character Information, Dual	3-14
Control Familiarization	2-5
Coordinate Computing Data	3-8
Coordinate Conversion Charts, Use Of	3-3
Cross-hair Controls	2-5, 2-14
Cross-hair Cursor	1-3, 2-13, 3-1, 3-9
CTRL	2-5
D	
Dark Vector	3-1
TEKTRONIX Data Communication Interface	3-15, 3-16, 5-12
Data Communication Interfacing	5-11
Deserialization	5-12
Desk-Top Operation	5-1
Direct Connection	5-3
Display Mounting Procedure	5-1
E	
Establishing Computer Communication	2-6, 5-3
F	
Familiarization and Checkout	2-1
Fully Written Condition	2-7
G	
Glossary of Terms	5-15
Graphic Input	3-9
Graphic Input Checkout	2-13
Graphic Input Mode	2-13
Graphic Plot	3-2
Graphic Plot Checkout	2-10
Graphic Plot Mode	2-10
H	
H C Int	2-2
Hard Copy Mode	2-15, 3-11
Hold Mode	2-9, 3-1
Home	2-7, 2-9

	Page
I	
Initial Turn-on	3-1
Installation	5-1
Interfaces, Additional	5-14
Interfacing Consideration	5-5
Interfacing Information	5-5
L	
Light Vector	3-1
Linefeed	3-15, 3-16
Line Names	5-7
Local Echo	3-15, 3-16, 5-14
LOCAL/LINE	2-5
M	
Margin 1	2-9
Margins	2-9, 3-1
Minibus Extender Option	5-5
Minibus Structure	5-5
Modem/Computer Connections	3-15, 3-16
Motherboard (Minibus) Connector	5-6
O	
Operating Modes	2-6, 3-1
Optional Character Set	3-1
P	
PAGE	2-3
Page Full Break	3-15, 3-16, 5-14
Page Full Busy	3-15, 3-16
Phone Line Connection	5-4
Power Switch	2-1, 2-2
Programming Considerations	3-1
R	
RESET	2-3
RETURN	2-4
RUB OUT	2-4
S	
Safety Considerations	5-2
Serialization	5-12
SHIFT	2-4
Software	1-2
Space Bar	2-4
Strappable Options	3-11, 3-16
Switch 1, 2 & 3	2-2
System Description	1-1
T	
TC-1	3-15, 3-16
TC-2	3-15, 3-16
V	
View Mode	3-1
View and Hold Mode	3-1
X	
X Axis	2-10
Y	
Y Axis	2-10