Catalog Number 26-1191

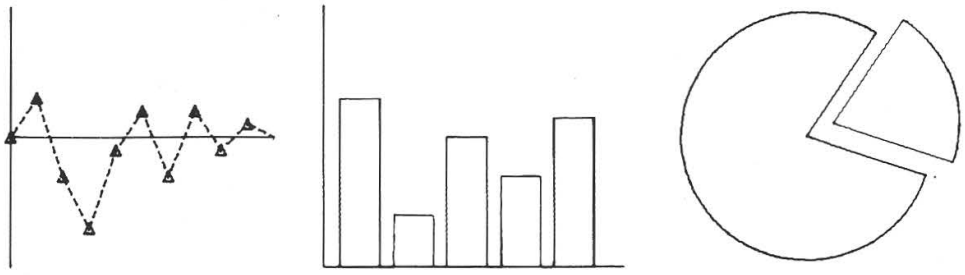
TRS-80® Multi-Pen Plotter

Radio Shack®
TRS-80
COMPUTER PRODUCTS

Radio Shack®

A DIVISION OF TANDY CORPORATION

MULTI-PEN PLOTTER



LINE GRAPHS BAR CHARTS PIE CHARTS

CUSTOM MANUFACTURED FOR RADIO SHACK A DIVISION OF TANDY CORPORATION

The FCC Wants You to Know . . .

This equipment generates and uses radio frequency energy. If not installed and used properly, that is, in strict accordance with the manufacturer's instructions, it may cause interference to radio and television reception.

It has been type tested and found to comply with the limits for a Class B computing device in accordance with the specifications in Subpart J of Part 15 of FCC Rules, which are designed to provide reasonable protection against such interference in a residential installation. However, there is no guarantee that interference will not occur in a particular installation.

If this equipment does cause interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient the receiving antenna
- Relocate the computer with respect to the receiver
- Move the computer away from the receiver
- Plug the computer into a different outlet so that computer and receiver are on different branch circuits.

If necessary, you should consult the dealer or an experienced radio/television technician for additional suggestions. You may find the following booklet prepared by the Federal Communications Commission helpful: *How to Identify and Resolve Radio-TV Interference Problems.*

This booklet is available from the US Government Printing Office, Washington, DC 20402, Stock No. 004-000-00345-4.

Warning

This equipment has been certified to comply with the limits for a Class B computing device, pursuant to Subpart J of Part 15 of FCC Rules. Only peripherals (computer input/output devices, terminals, printers, etc.) certified to comply with the Class B limits may be attached to this computer. Operation with non-certified peripherals is likely to result in interference to radio and TV reception.

Contents

Introduction

The TRS-80® Multi-Pen Plotter has been produced with you in mind and its rugged design should provide years of reliable service. It is easily operated, requires little attention and care, yet is capable of producing a variety of points, lines, curves and characters — *all in different colors!*

The Multi-Pen Plotter can be used with a TRS-80 Model I, II, III, or Color Computer in conjunction with a variety of other Radio Shack computer add-on's to give you a powerful computer system.

There are 93 upper- and lowercase printable characters plus six marker symbols available for your use. Its control panel includes a power switch and pen up, pen down and pen positioning capabilities. The Plotter has a self test capability which draws a plot that lets you know if your Plotter is functioning properly.

Other outstanding features include:

- A Six-Pen Changer for multi-color graphs, charts, or diagrams.
- A Touch Control Panel that allows Manual or Remote control.
- A data buffer of 768 bytes that remembers instructions.
- Resolution of 200 increments (steps) per inch at a constant rate of plotting.

and more!

This manual will:

- Show you how to connect and use the Multi-Pen Plotter.
- Describe the programming commands necessary to use with your Computer with the Plotter.
- List Driver Routines for TRS-80 Model I, II, III, and Color Computer. You'll need to include a Driver Routine in any program you write for the Plotter before your Computer will recognize Plotter commands. (This includes examples used in this manual; load the Driver Routines, then try the examples.) See Appendix A.
- Describe how to use Tandy-Graph, the powerful plotting program contained on diskette. (Note: Tandy-Graph is not available for Color Computer.) See Appendix B.

1/ Description of the Plotter

Before doing anything else, be sure the following accessories are included in the Plotter package:

1 Multi-Pen Plotter
1 Power Cord
1 package Pens
1 package Fuses and Wrench
1 Dust Cover
1 Owner's Manual

Identification of Controls

Using Figure 1 as a guide, read through the following descriptions and familiarize yourself with the Plotter.

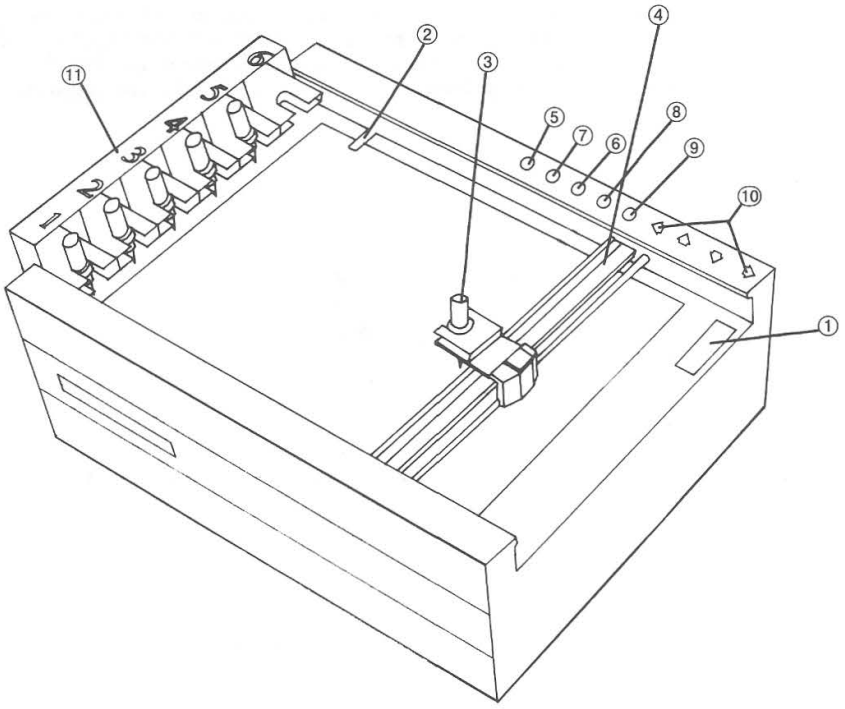


Figure 1. Front View

① **CHART.** When set to the LOAD position, this slide relieves tension on the PAPER HOLDDOWN CLAMPS and allows you to insert or remove the paper. When set to the HOLD position, the paper is secured. Be sure that the paper is secure before plotting begins.

② **PAPER HOLDDOWN CLAMPS.** The PAPER HOLDDOWN CLAMPS are linked to the CHART slide. These clamps secure the paper when the CHART slide has been set to the HOLD position.

③ **PEN.** The PEN is the Plotter's writing device. It is held in place by the PEN HOLDER and moves along the Plotter's BEAM (the Y-axis).

④ **BEAM.** Moves the PEN and PEN HOLDER along the Plotter's X-axis.

⑤ **RESET.** Clears Plotter memory and resets the Plotter. RESET must be pressed before you can change operation modes (see REMOTE and MANUAL).

⑥ **REMOTE.** Allows the Computer to control the Plotter. Before you can run a program, you must be sure that you set the Plotter in the Remote Mode by pressing REMOTE.

⑦ **MANUAL.** Allows you to control the Plotter. When the Plotter is in the Manual Mode, you have control of the PEN positioning. MANUAL also disables Remote plotting.

⑧ **PEN UP.** Manually raises the PEN from the plotting surface.

⑨ **PEN DN.** Manually lowers the PEN to the plotting surface.

⑩ ◇, ◇, ◇, ◇. These switches cause PEN and/or BEAM movement in the indicated direction(s). These are active when the Plotter is set to Manual.

⑪ **PEN CHANGER.** Holds a "stable" of different colored pens. The individual PEN HOLDERs are identified as "stalls." The Pens are placed in their stalls in the color arrangement specified in Table 1. (You may change this arrangement; however, all references to stall numbers and pen colors in this manual will be based upon this system.)

Stall Pen-Color Arrangement	
Stall #	**Color**
1	Black
2	Red
3	Blue
4	Green
5	Violet
6	Orange

Table 1

X and Y Orientation. The X and Y orientation of the Plotter is illustrated in Figure 2.

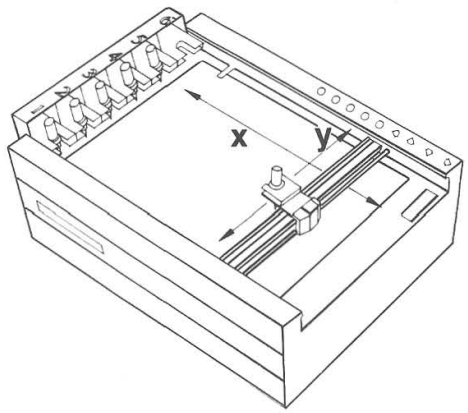


Figure 2. X-Y Orientation

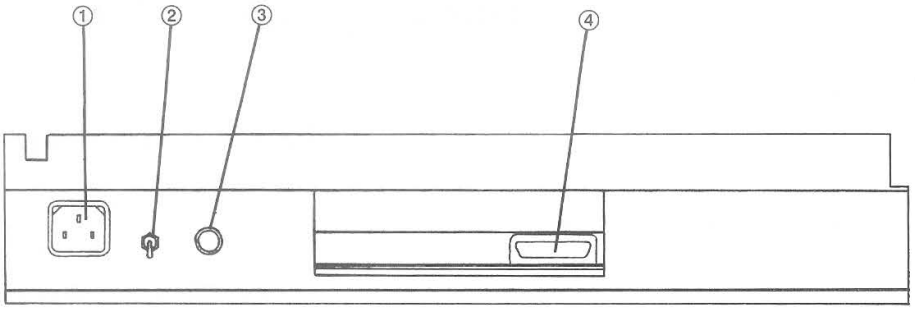


Figure 3. Plotter (Rear View)

① **Power Cord.** Connects the Plotter to a wall-mounted 115 VAC electrical outlet.

② **Power ON/OFF Switch.** Turns the power to the Plotter ON or OFF. When the Switch is in the down position, power is OFF.

③ **Fuseholder.** Holds the 1/2 amp fuse which is used to protect your Plotter from a circuit malfunction. Replace only with the same type and rating of Fuse.

④ **RS-232 Connector.** Accepts a DB-25 connector (plug) for connecting the Plotter to your Computer.

Paper. A smooth, 20 lb., #1 (white) sulfite, or better quality, paper should be used to produce normal quality graphics. For permanent and superior quality graphics, a smooth 20 lb., water mark, 50% cotton content, or better quality, typewriter paper is recommended.

PENs. Ball-point pens are available for use with the Plotter. See Table 2 for details.

PEN Color	Ball Point (for paper)	Felt Tip (for transparencies)
RED	26-1460	26-1470
BLUE	26-1461	26-1471
GREEN	26-1462	26-1472
VIOLET	26-1463	26-1473
BROWN	26-1464	26-1474
ORANGE	26-1465	26-1475
BLACK	26-1466	26-1476

Table 2

2/ Setting Up the Plotter

To become better acquainted with your TRS-80 Plotter, follow the steps below.

Mechanical Check

Before using your Plotter, be sure there is a slight (but constant) resistance to movement of the PEN and BEAM by manually moving the BEAM along the X-axis (left and right). Push the BEAM back and forth several times.

When the BEAM is stationary, manually push the PEN HOLDER along the BEAM on the Y-axis. (See Figure 4) Then push the PEN HOLDER in the reverse direction. Do this several times. You should feel a slight, constant resistance to movement. There should be no sudden increase or decrease to the resistance.

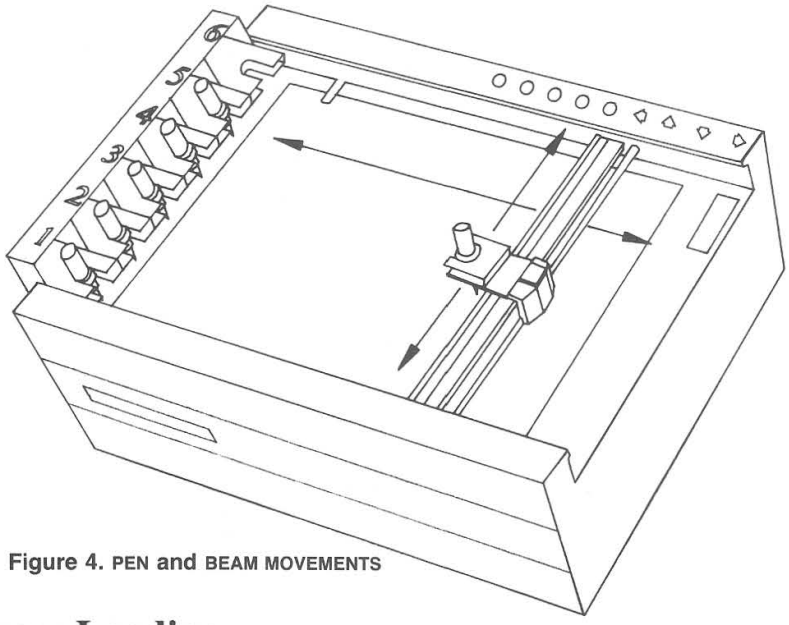


Figure 4. PEN and BEAM MOVEMENTS

Paper Loading

Important Note: When you handle paper that is to be loaded into the Plotter, do not touch the area which is to be printed on. Handle the paper by the edges only! Finger prints leave a slight residue on the paper and ball-point pens will skip over the areas which have been handled.

When you're ready to load paper onto the Plotter, refer to Figure 5 and follow the sequence below.

1. Push the CHART slide in the LOAD position. This raises the PAPER HOLDDOWN CLAMPs.
2. Place the paper on the platen. Position the paper under the PAPER HOLDDOWN CLAMPs and against paper stop (located on the left side of the platen, under PEN STALL's # 3 and 4).
3. Set the CHART slide to the HOLD position.

Paper loading is complete.

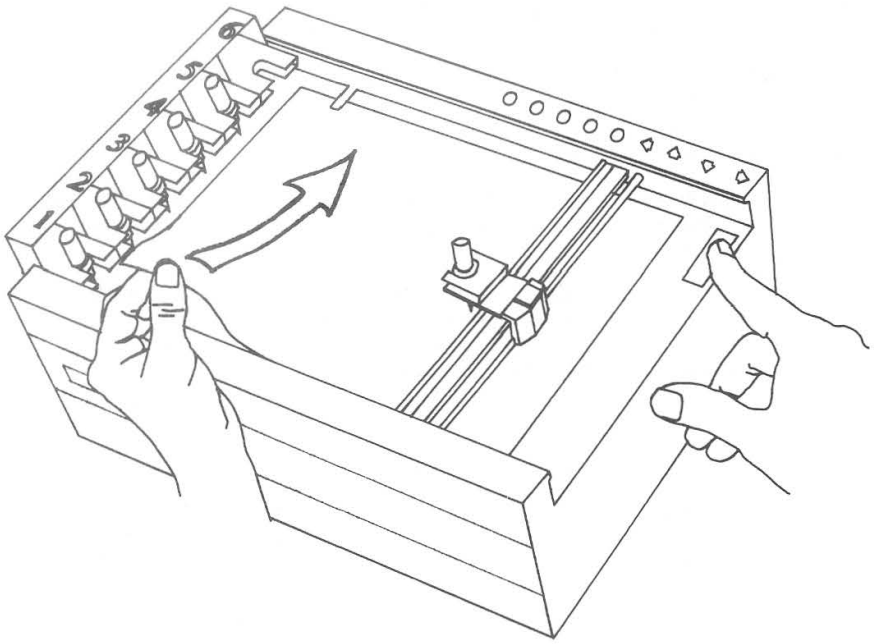


Figure 5. Paper Loading

PEN Installation

1. Remove the protective cap from the PEN.
2. Rub the pen point vigorously on a piece of scrap paper until the ink begins to flow.
3. Insert the PEN into the PEN HOLDER. Be sure the largest diameter of the PEN is properly seated and secured in the socket by the retainer fingers of the PEN HOLDER.

Note: PEN installation is the same for the PEN STALLS. When PENs are not in use, *always replace the protective cap*.

PEN Pressure Adjustment

If your PEN skips while plotting, first load a clean sheet of paper into the Plotter. Be sure to hold the paper by the edges! Then begin plotting again. If the skipping continues, you may need to adjust the PEN pressure. To do so, turn the Hex screw in the PEN HOLDER slightly in a clockwise direction.

Powering Up the Plotter

1. Connect one end of the power cord to the POWER jack on your Plotter.
2. Connect the other end to a 115 VAC wall outlet.
3. Turn the Plotter's Power switch ON.

Manual vs. Remote Operation

The Plotter has two modes of operation — Manual (selected by pressing the MANUAL Switch) and Remote (selected by pressing the REMOTE Switch). When the Plotter is in the Manual Mode, you control the Plotter by pressing the directional (◊, ◊, ◊, ◊,) and PEN UP and PEN DN switches. When the Plotter is in Remote Mode, the Computer controls the Plotter and its actions are determined by the program you're running in the Computer.

For MANUAL operation:

1. Be sure the power is ON.
2. Press RESET.
3. Press MANUAL.

You now have manual (local) control of your Plotter.

PEN Action

Before a PEN is inserted in the PEN HOLDER, read the following section and perform the suggested operations. First though, manually move the BEAM and PEN HOLDER to the approximate center of the paper.

Set the Plotter in Manual Mode and start by pressing the switch labeled PEN DN. The PEN HOLDER will "drop" down with a slight click. (After approximately three seconds, the PEN HOLDER should automatically go up. Don't press another switch during this period.)

Now, press PEN UP and the PEN HOLDER should go back up.

Repeat this a few times until you're familiar with this operation.

PEN and BEAM Movements

With the PEN HOLDER remaining in the center of the paper, press and hold ◊. The BEAM will move to the left along the X-axis and the PEN HOLDER will go down as if to plot.

Note the BEAM moves slowly at first with a dull stepping sound. It then begins to move much faster with a humming sound. The slow movement of the BEAM (or PEN) allows you to precisely position the PEN. In Plotter terminology, this is known as "jogging."

When ◊ is released, movement stops immediately. (Don't allow the PEN HOLDER to "bump" into the PEN STALLS.)

Press ◊. The BEAM will move back towards the center of the plotting area.

Now press ◊ and the PEN HOLDER will move towards you along the Y-axis. When you press ◊, the HOLDER will move up along the Y-axis.

Again with the PEN HOLDER in the center of the plotting surface, try pressing ◊ and ◊ at the same time. This combination enables the PEN HOLDER to move on a diagonal to the upper right corner of the plotting area. Diagonal movement can be performed in any direction by pressing the appropriate switch combinations.

Now load a PEN into the PEN HOLDER by positioning the PEN HOLDER in front of the desired STALL and pressing ◊. When the HOLDER has "latched on" to the PEN, press ◊ to back the PEN out onto the plotting surface. (You can then perform all of the operations described above. This time, however, you will be plotting actual points on the paper.)

SELF-TEST

Are you about ready to see some of the real power of the Plotter? Okay, but first be sure all of the PENs are in the proper STALL.

In Manual Mode, you can press ◊ and ◊ at the same time to start the Plotter's SELF-TEST. This produces the plot illustrated in Figure 6. When you run the SELF-TEST on your Plotter, compare it to Figure 6. If they are identical, you'll know the Plotter is functioning properly.

Remote Operation

When you press RESET and then press REMOTE, the Plotter enters Remote Mode and the Plotter is controlled by the Computer. For more information, see **Using the Plotter** later in this manual.

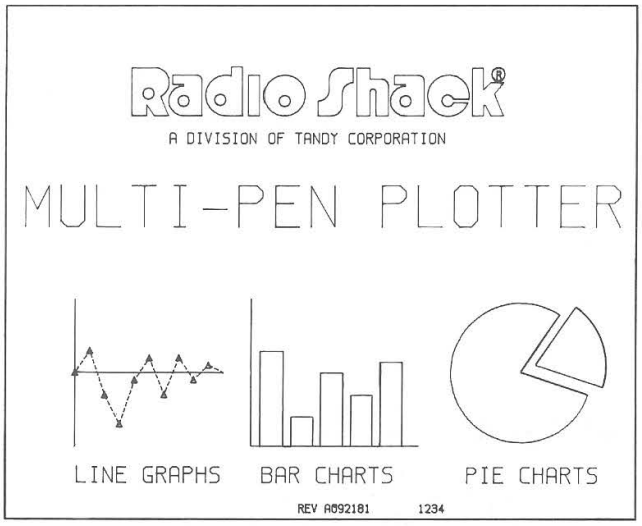


Figure 6. SELF-TEST Plot

Connecting the Plotter to the Computer

Before you can connect the Plotter to your Computer, you must be sure that you have the correct cable for your Computer. Table 3 specifies which cable you need for the TRS-80 you have.

Plotter-to-Computer Cables

TRS-80	Cable Catalog #
Model I	26-1145*
Model II	26-4403
Model III	26-1408
Color Computer	26-3014

Table 3

* The Model I RS-232-C cable is supplied with the RS-232-C Interface Board (26-1145). See your Radio Shack Computer Center for details.

See Figure 3 for the location of the RS-232-C jack on the back of the Plotter.

The location of your Computer's RS-232-C jack depends on which TRS-80 you have. Table 4 provides quick instructions for locating your Computer's RS-232-C jack; see your Computer's owner's manual for more specific details.

TRS-80 RS-232-C Location

Computer	Location
Model I	Front of the Expansion Interface
Model II	Rear of the Computer
Model III	Underneath the Computer
Color Computer	Rear of the Computer

Table 4

To connect the Plotter to your Computer:

1. Be sure the Computer and Plotter's power are OFF.
2. Plug the appropriate end of the connecting cable into the Plotter's RS-232-C jack.
3. Plug the other end of the cable into the Computer's RS-232-C jack.
4. Power-up the System as described in your Computer's owner's manual.

The System is now ready for use.

Baud Rate

The TRS-80 Plotter is designed to operate at a fixed 2400 baud. You must be certain that your Computer is set to operate at the same rate (2400 baud). Effective exchange of data will occur at this rate. See your Computer's owner's manual for details.

The RS-232-C Interface is a design standard (EIA RS-232C) which accommodates the exchange of information in a serial bit stream of various transmission (baud) rates at specified signal levels. The interface defines specific pin connections in a DB-25 subminiature type connector for use in communication devices.

Plotter protocol is: 2400 Baud, 8 bits, no parity, and 2 stop bits.

3/ Using the Plotter

Once the Plotter and Computer are properly connected and powered-up, be sure the Plotter is in the Remote Mode (press RESET, then press REMOTE).

However, before you can begin using the System, you'll have to become familiar with the commands the Plotter understands. These commands are understood by the Plotter and are compatible with computer languages such as BASIC, PASCAL, FORTRAN, and other high-level computer languages.

The codes which are used in Plotter language (called DM/PL) consist of ASCII characters transmitted from your TRS-80 to the Plotter. Plot command instructions may consist of a single or dual character(s), or the character(s) followed by additional information. All the commands are contained in Appendix C. Each of these commands will be discussed in more detail later in this section.

Programming Hints and Tips

- Plotter Commands need to be separated from each other by a comma or a space.
- A value (integer) which is not signed will be a positive value. A negative X or Y value must always be specified with a minus sign (− 14, − 616, etc.).
- "Handshakes" always occur between data blocks of 256 bytes or less. Your Computer should be programmed to transmit data in block sizes of 256 bytes, or less, followed by a CR (0D16) prompt code. The Plotter will always respond with a CR (0D16) if it can receive 256 bytes of data.
- After connections are completed and your Plotter is in Remote Mode, data can be input to your Plotter. The microprocessor in your Plotter constantly scans all incoming data but acts only after the Plotter receives a select code (;:).
- Never start a program with a PEN in the PEN HOLDER.
- Always be sure the program ends with an empty PEN HOLDER.

Converting Plotter "Steps" to Inches

The basic unit of measurement for the Plotter is a "step" which is defined as a .005 inch increment in either the X or Y direction. There are 200 steps in one inch.

You'll have to keep this in mind when writing any programs for the Plotter. If you need to plot a line four inches long, your program will need to take 4 (inches) x 200 (steps) = 800 steps in the X or Y direction to produce that line.

The maximum size of the plotting area is X = 1850 steps (9¼") by Y = 1400 steps (7").

Plotter Commands

Command syntax is a command's general form (like the grammar or structure of an English sentence). The syntax tells how to use Plotter Commands together with the necessary parameters and punctuation.

In the following discussion of Plotter Commands, we will tell you:

- What the key or key-combination is you'll have to type to enter the Command.
- What the Command does.
- What the Command syntax is.
- A brief discussion of what the command does.
- And, in most cases, an example of how to use the command.

Be sure to use the appropriate Driver Routine when using the examples detailed in this section.

;:

Plotter Select

```
;:
```

This command tells the Plotter that your Computer has selected the Plotter for an operation. A Plotter Select (;:) is always needed after a Reset Command is entered.

This command must be at the beginning of the program. Once the Plotter is selected, it remains selected until the program issues a Deselect (@) or Reset (Z) Command.

Note: A Plotter Select given any time after a Reset has been executed will cause the Plotter to automatically select PEN #1 as a part of the select initialization routine.

@

Plotter Deselect

```
@
```

After the Plotter has received Plotter Deselect (@), it will ignore all further input until it again receives the Plotter Select (;:) from the Computer. A power loss will cause the Plotter to be Deselected.

Z

Plotter Reset

```
Z
```

This command resets the Plotter. This is the same as pressing the RESET switch. You will have to issue another Plotter Select (;:) before the Plotter can begin Remote operation.

T

Plotter Test

```
T
```

T selects a self-test routine that tests the Plotter's logic and then draws the SELF-TEST Plot (See Figure 6).

All previously specified plot commands are lost when T is issued. Plotter Select must be repeated after T is executed.

Example

```
;:T
```

After the Computer selects the Plotter (;:), the SELF-TEST will be plotted.

D
Pen Down

```
D
```

D causes the Plotter to lower the PEN to the plotting surface. The PEN remains in the down position until a command U, H, or Z is received by the Plotter. Turning off the Plotter's power will also cause the PEN to rise.

Example

```
;:D
```

U
Pen Up

```
U
```

U tells the Plotter to raise the PEN. U remains in effect until command D is executed or until a Pen Down is executed in another command.

Example

```
;:U
```

P
New Pen

```
Pn
n is a numeric expression between 0-6 and specifies a PEN STALL. n must be specified.
```

P tells the Plotter to immediately execute a Pen Up operation and return the PEN (currently in the PEN HOLDER) to its proper PEN STALL. The Plotter then selects the specified new PEN and resumes its plotting operation at the last plotting position. The command P must be given each time a new PEN is desired; the PEN number (*n*) must be given — there is no default.

Except for the numerical value 0, a Pen Down is automatically executed exactly upon reaching the last plotting location.

Zero is commonly used before a Plotter Deselect (@) is given. Therefore, the Plotter will be ready with an empty PEN HOLDER at the Home (H) position.

Note: An example will be given and covered after Home, Origin, Line Types, and Absolute Pen Positioning are discussed.

H
Home Position

```
H
```

This command tells the Plotter to raise the PEN and move to the Home position. Any previously selected command A (Absolute), R (Relative), or L (Line) is retained except O (Origin) which will now be defined as the Home location, i.e., the lower left corner of the plotting surface. (See Figure 7).

Example

```
;:H
```

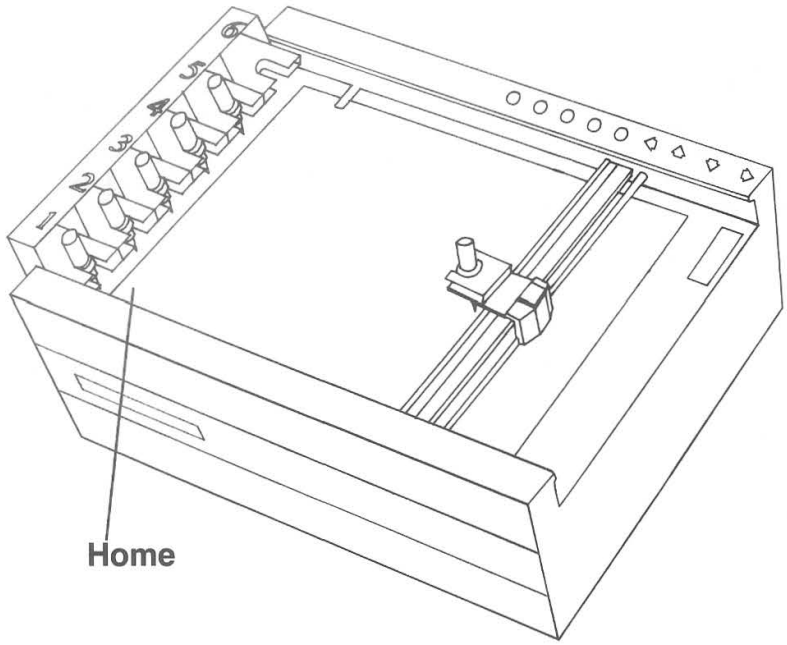


Figure 7. Home Position

O
Sets Plot Origin

```
O
```

The O command specifies the current PEN location as the "origin" of your plotting system. It may be used at any time. The new origin is then retained until:

- Plotter Reset (Z) is issued.
- Another Origin (O) command is given.
- A Home (H) command is given.

Example

```
;:O
```

sets the current PEN location as the plot origin.

```
;:H
```

erases the "origin" specified by O.

L
Line Types

```
Ln
```

***n* is a numeric expression from 0-9 and specifies the line to be drawn by the Plotter. *n* is optional, if omitted, 0 is used.**

Ten different line types are available to enhance the readability of more complex plots. The ten line types are shown and identified in Table 5. Once a line type is selected, it remains selected until:

- A new Line Type (L*n*) is selected.
- A Reset (Z) command is given.
- A New Pen (P) command is given.

The New Pen command (P) automatically resets the Line Type to zero. The Plotter will then draw a solid line from the departed position. Unless a solid line is desired, you must respecify the Line Type after the New Pen command.

Line Types

Line Number	Line Example
L0	————————
L1	.....
L2	- - - - - - - - - - - - - - - - - - - -
L3	----------
L4	— — — — — — — — — — — —
L5	- - - - - - - - - - - -
L6	— — — — — — — — — — — —
L7	— — — — — — — — — — — —
L8	—— —— —— —— ——
L9	—— —— —— —— ——

Table 5

A
Absolute Pen Positioning

A*x,y*

***x,y* specifies a point on the plotting surface which is to be the Origin. *x* is a numeric expression 0-1850; *y* is a numeric expression between 0-1400.**

This command (A) selects the Absolute Pen Positioning-Mode. In this mode, PEN movement is made in relation to a specific point which you define. This point is the Origin.

The Plotter will remain in Absolute Pen Positioning Mode until:

- Relative Pen Positioning (R) is selected.
- A Reset (Z) command is given.
- The Plotter's power is turned OFF.

Example

```
:: HAD 0,600 600,600 600,0 0,0 U
```

The Plotter's actions are:

1. The Plotter is selected (;:).
2. The PEN first moves to the Home position (H).
3. Absolute Positioning Mode is next specified (A).
4. The PEN is lowered to the plotting surface (D).
5. The PEN is then moved to Absolute coordinate 0,600.

6. The PEN is moved to Absolute coordinate 600,600.
7. The PEN is moved to Absolute coordinate 600,0.
8. Finally the PEN is moved to Absolute coordinate 0,0 to complete the rectangle.
9. The PEN is then raised (U).

The Plotter is available for continued plotting in Absolute Positioning Mode.

Note that the Pen Down (D) command is required to plot a Line; the Plotter selected line L0 since no Line Type was given (see Table 5). Once on the plotting surface, the PEN remained down as the Plotter executed all commands in the program line. If a Pen Up (U) had not been included in the program and no other coordinate pairs or valid commands were received by the Plotter, the PEN would rise automatically after approximately three seconds. Also, the Absolute (A) command is not required between coordinate pairs after PEN movement begins.

Example

```
:: P3 HAD 200,300 P2 L1 500,200 U
```

This example includes New Pen (P) and Line Type (L) selections.

The Plotter actions in sequence are:

1. The Plotter is selected (:).
2. The PEN HOLDER is moved to STALL #3 and grasps the PEN (P3).
3. The PEN HOLDER moves to the Home position (H).
4. Absolute Positioning Mode is specified (A).
5. The PEN is lowered (D).
6. The PEN is moved to Absolute coordinates 200,300 and a solid blue line connects points 0,0 to 200,300 (A) (0).
7. A Pen Up occurs at departed point (200,300).
8. The PEN HOLDER returns the PEN to STALL #3 (P2).
9. The PEN HOLDER is moved to STALL #2 and grasps the PEN (P2).
10. The PEN HOLDER returns to the departed point (200,300) (P2).
11. A Pen Down occurs and a red dotted line is drawn from points 200,300 to 500,200 (A) (L1).
12. A Pen Up occurs (U).

Note: A Plotter Select (:) entered at any time after a RESET (Z) will cause the Plotter to automatically select PEN 1 as a part of the select initialization routine. Because of this routine, the PEN HOLDER will be empty and at Home (H) position. The PEN HOLDER will move and grasp PEN 1 and a solid line (L0) will be drawn by the Plotter from 0,0 to 200,300 since a Line Type was not selected. Thereafter, the Plotter responds to Computer commands.

Example

```
:: P3 HAD 100,200 200,200 300,600 P2L1
400,400 P3 500,500 P2L1 600,300 P3 700,300
P6L1 OA -100,-100 0,200 P3 100,0 0,300 L8
-100,0 -100,-100 U P0HZ
```

This example illustrates the use of New Pen and Line Type selections. Note the change in Origin during the plotting sequence. All points are in the Absolute Pen Positioning Mode and the dimensions are stated in Plotter steps.

The Plotter's actions in sequence are:

1. The Plotter is selected (:).
2. The Plotter then moves to and grasps PEN 3 (P3).
3. The Plotter moves to Home position and Origin is established at this location (H).

4. Absolute Positioning Mode is specified (A).
5. The PEN is lowered to the plotting surface (D).
6. The PEN is moved to absolute coordinates 100,200, drawing a solid blue line (A).
7. The PEN continues to draw a solid blue line to 200,200 (A).
8. The solid blue line is then continued to point 300,600 (A).
9. A Pen Up occurs and PEN 3 is returned to its STALL; PEN 2 is grasped and the Plotter returns to 300, 600; a Pen Down occurs and a dotted red line is drawn to 400,400 (P2) (L1) (A).
10. A Pen Up occurs and PEN 2 is returned to its STALL; PEN 3 is grasped and the Plotter returns it to 400, 400; a Pen Down occurs and a solid blue line is drawn to 500,500 (P3) (A).
11. A Pen Up occurs and PEN 3 is returned to its STALL; PEN 2 is grasped and the Plotter returns it to 500,500, Pen Down occurs and a dotted red line is drawn to 600,300 (P2) (L1).
12. A Pen Up occurs and PEN 2 is returned; PEN 3 is grasped the Plotter returns to 600,300, Pen Down occurs and a solid blue line is drawn to 700,300 (P3).
13. Pen Up occurs, PEN 3 is returned; PEN 6 is grasped and the Plotter returns to 700,300. A new Origin is established, Pen Down occurs and an orange dotted line is drawn to −100,100 (P6) (L1) (0) (A). The orange dotted line continues to 0,−200 (A).
14. Pen Up occurs. PEN 6 is returned to its STALL; PEN 3 is grasped and moved to 0,−200; a Pen Down occurs, and a solid line is drawn to 100,0 (P3) (A).
15. The solid blue line continues to 0,300 (A).
16. A long dashed line is continued to (−100,0) (L8) (A).
17. The dashed line is continued to −100,−100.
18. A Pen Up occurs and the PEN is placed in STALL #3. The empty pen changer is returned to the Home position; Origin is established at 0,0 (P0) (H).
19. The Plotter is RESET.

R
Relative Pen Positioning

R*x,y*
***x,y* specifies a point on the plotting surface which is to be the Origin. *x* is a number between 0-1850; *y* is a number between 0-1400.**

Relative Pen Positioning is very similar to Absolute Pen Positioning. However, the PEN is now moved to its next position based on its current (or relative) position. There is no defined origin in this command.

Example

```
:: HRD Ø,6ØØ 6ØØ,Ø Ø,-6ØØ -6ØØ,Ø U
```

This command line will plot a box about three inches in size using relative vectors rather than absolute vectors. Here is the sequence:

1. The Plotter is selected (;:).
2. The PEN is moved to the Home position (H).
3. The Relative Pen Positioning Mode is specified (R).
4. The PEN is lowered (D).
5. The PEN is moved 0 steps in the X direction, 600 steps in the Y direction from the Home position (R).
6. The PEN is next moved 600 steps in the X direction, 0 steps in the Y direction (relative to the last achieved position−0,600) (R).
7. Then the PEN is moved 0 steps in the X direction, 600 steps in the negative Y direction (relative to present position−600,600) (R).
8. The PEN is finally moved 600 steps in the negative X direction, 0 steps in the Y direction (relative to present position−600,0) (R).

9. The PEN is then raised (U).

Note: A Pen Down command was given to produce the line. The first movement in Relative Pen Positioning was based on the PEN's present position at Home (0,0). Each movement after that in Relative Mode was based on the current position.

Example

```
:: RD 0,200 L3 200,0U
```

In this example:

1. The Plotter is selected (::).
2. The Relative Pen Positioning Mode is specified (R).
3. The PEN is lowered (D).
4. The PEN is moved 200 steps (from current position) in the Y direction, leaving a solid line. (The Plotter selected L0 because Line Type was not specified) (R).
5. The dashed line is selected (L3).
6. Then the PEN is moved 200 steps (current position) with the resulting dashed line and the PEN is raised (R) (U).

In this example, the first movement was based on the current location of the PEN. There is no need to establish the Origin. A Pen Down command must be given to produce the line.

x,y
Move to Specified Coordinates

x,y
***x,y* specifies a point to move to. *x* is a numeric expression between 0-1850; *y* is a numeric expression between 0-1400.**

The Plotter uses a coordinate position as a GOTO statement, as next Pen position information, or as an executable command. When this command is entered, the PEN is moved to the specified X-Y coordinates before the next command is executed. The PEN *may* be up or down during the motion. It must be lowered by command when used in Absolute or Relative Pen Positioning modes.

Example

```
::RD 0,200
```

In this example $x = 0$ and $y = 200$.

S
Character Plotting

S*rh* CHR$(*n*)__
***r* specifies the degree of rotation and is a numeric expression between 1-4. 1=0 degrees: 2=90 degrees: 3=180 degrees: 4=270 degrees**
***h* specifies the character's height and is a numeric expression between 1-9.**
CHR$(*n*) – the ASCII character where *n* is a numeric expression between 32-126 decimal. (A string of alphanumerics may be used).
__ indicates the end of the string and exits character plotting mode.

The S command causes the Plotter to plot alphanumeric characters. There are 93 printable ASCII characters. These may be rotated in four directions and drawn in nine different sizes. An underscore (5F HEX) indicates the end of the character string and the end of Character plotting. BASIC can produce the underscore character with the command CHR$(95). The ASCII character string to be drawn may extend beyond a source data buffer. If so, then a CHR$(94) (5E HEX) must be sent before the prompt code.

Remember, the underscore (5F HEX) is required for you to exit Character plotting.

Code #	Rotation
1	0
2	90 degrees
3	180 degrees
4	270 degrees

Table 6

Code #	Height (inches)
1	.070 inch
2	.105 inch
3	.14 inch
4	.21 inch
5	.28 inch
6	.42 inch
7	.56 inch
8	.85 inch
9	1.12 inch

Table 7

Example

```
10 LPRINT ";: H A 0,800 S13 TANDY"; CHR$(94)
20 LPRINT "MULTI-PEN"; CHR$(95)
30 LPRINT "0,500 S13 PLOTTER"; CHR$(95)
```

In this example:

1. The Plotter is selected (;:).
2. The PEN moves to the Home position (H).
3. Absolute plotting is specified (A).
4. The PEN moves 800 steps in the Y direction (A).
5. No Rotation and character size 3 (height = .14 inch) are specified (S).
6. The word TANDY is drawn (S).
7. CHR$(94) is sent preceding the prompt code CR (0D16).
8. The prompt code CR (0D16) is sent at the end of the print line (S).
9. MULTI-PEN is drawn following the word TANDY (S).
10. The PEN moves to coordinates 0,500 (A).
11. The PEN draws the word PLOTTER (S).
12. Symbol Mode is exited when the Plotter receives the underscore.

M
Marker Plotting

M*hm*

***h* is a numeric expression between 1-5 and specifies the marker height.**
***m* is a numeric expression between 0-5 and specifies the marker type.**

M, followed by two numbers, will cause the Plotter to draw a marker symbol at a specified size. There are six different symbols for your use.

Code Marker Symbols

Code #	Marker
0	+
1	×
2	□
3	⬡
4	△
5	[X]

Table 8

Code Size

Code #	Marker Size
1	.07 inch
2	.14 inch
3	.28 inch
4	.56 inch
5	1.12 inch

Table 9

Example

```
;: M34
```

In this example, the Plotter will draw a triangle .28″ high.

Note: If another Marker symbol is desired at an adjacent position, then another entry in the identical format must be made; one entry must be made for each Marker desired. Previously selected plot commands are retained.

CC
Circle Plotting

CC*x,y*

***x,y* specify the center of the circle to be plotted. *x* and *y* may be numeric expressions between −32767 and +32767.**

CC, followed by X and Y coordinates, will generate a circle. The current Pen position is on the circumference and the beginning of the circle. The X and Y coordinates identify (in Plotter steps) the center of this circle relative to the current Pen position. The center of the circle can be a point off the plotting surface. The values of the X and Y coordinates may be specified to ±32767 Plotter steps.

Example

For an example, the Origin (0,0) is the Home position and the following command is entered:

```
;:CC 200,0
```

1. The Plotter is selected (;:).

2. The PEN is lowered (CC).
3. The Plotter moves the PEN through a semi-circle in a counter-clockwise direction on the positive quadrant of the Plotter's coordinate system. The beginning point of the circle is (in Plotter steps) 0,0, the upper most point is 200,300, and the furthest right point is 460,0. (CC) (200,0)
4. After about three seconds, the PEN is raised.

CA
Arc Plotting

CA *x,y degrees*
***x* and *y* specify the center of the circle which contains the arc to be plotted and are numeric expressions between −32767 and +32767.**
***degrees* specifies the size of the arc and is a numeric expression between −360 and +360.**

CA, followed by X-Y coordinates and degrees information, will generate an arc. The current Pen position is on the circumference of the circle and is the beginning of the arc. The X and Y coordinates identify the center of the circle the arc would form if degrees were specified as 360. The values of the X and Y coordinates may be specified to +/− 32767 steps.

The Plotter draws the arc in a counter-clockwise direction when the sign of the angle is positive and clockwise when the sign is negative.

The resolution of the arc is ± one degree.

Example

An example that illustrates the use of multiple Circle and Arc plotting follows. The example also includes the use of the Character and Marker plotting plus New Pen and Line Type selections.

```
:: P1 HAD 200,300 L1 600,300 L0 800,0 U 200,300
CA 400,0-60 600,300 CA -400,0 60 400,650 P3
CC 0,440 CC 0,400 CC 0,383 190,303 P2S14 LAST EXAMPLE_
400,1090 M20 400,1050 M21
400,1033 DM25 400,1050 M35 P0HZ
```

The Plotter sequence of actions are:

1. The Plotter is selected (:)
2. The PEN HOLDER is moved to STALL #1 and grasps the PEN and moves to Home (P1) (H).
3. Absolute Pen Positioning Mode is specified (A).
4. The PEN is lowered (D).
5. The PEN is moved to coordinates 200,300; a solid line is drawn (A).
6. A Line Type selection is made at 200,300; the PEN continues to move to 600,300; a dotted line is drawn (L1) (A).
7. A Line Type selection is made at 600,300; the PEN continues to move to 800,0; a solid blue line is drawn (L0) (A).
8. The PEN is raised and moved to 200,300 (U) (A).
9. The PEN is lowered at 200,300; in a clockwise direction, a 60 degree Arc is drawn (A) (CA).
10. The PEN is raised and moved to 600,300 (A)
11. The PEN is lowered at 600,300; in a clockwise direction, a 60 degree arc is drawn.
12. The PEN is raised and moved to 400,650. PEN 1 is returned to its STALL; PEN 3 is grasped from its STALL and is moved to 400,650 (P3) (A).
13. The PEN is lowered at 400,650, and in a circle, whose origin is at 0,440 relative to current Pen position (400,650) is drawn counter-clockwise. (A) (CC).

14. In a counter-clockwise direction, a second circle (whose origin is at 0,400 RELATIVE to current PEN position 400,650) is drawn (A) (CC).
15. In a counter-clockwise direction, a third circle (whose origin is at 0,383 relative to current Pen position 400,650) is drawn. The PEN is raised (A) (CC).
16. The PEN is moved to 190,303; PEN 3 is returned to its STALL, PEN 2 is grasped from its STALL and is moved to 190,303 (P2).
17. The PEN is lowered at 190,303 and LAST EXAMPLE is drawn. The PEN is raised (S14).
18. The PEN is moved to 400,1090 (A).
19. The PEN is lowered at 400,1090 and a + (Marker Symbol) is drawn; the PEN is raised (M20).
20. The PEN is moved to 400,1050 (A).
21. The PEN is lowered at 400,1050 and an X (Marker Symbol) is drawn; the PEN is raised (M21).
22. The PEN is moved to 400,1033 (A).
23. The PEN is lowered at 400,1033 and an X (Marker Symbol) is drawn; the PEN is raised (M25).
24. The PEN is moved to 400,1050 (A).
25. The PEN is lowered at 400,1050 and an X (Marker Symbol) is drawn over the existing X; the PEN is raised (M35).
26. PEN 2 is returned to its STALL; the empty PEN HOLDER is returned to Home; the Origin is established at 0,0 (P0 H).
27. The Plotter is RESET (Z).

The continuation of the circle, wherever possible within the plottable surface area, is illustrated in the use of the three different diameter circles. Each circle is drawn in 72 equal segments from the current Pen position. If a full segment cannot be completed within the plotting area, a Pen Up will occur at the beginning of the segment. Consequently, the circumference of each circle will terminate at a different point within the plotting area.

Hints and Tips

- Always hold the paper by the edges when loading paper into the Plotter; ball-point pens will skip over areas which have been handled.
- If the Plotter seems inexplicably "hung up" for some reason, press RESET and try again.
- All previously specified commands are lost when Self Test (T) is entered. The Plotter Select (;:) command must be entered before the Plotter will respond.
- A satisfactory test plot initiated via the Self Test command, verifies that the system's electronics, mechanics and logic are properly functioning.
- Do not use ball-point pens for transparencies.
- Do not use felt-tip pens on paper; quality graphics will not be produced.
- Under some conditions, the Plotter may have difficulty "seeing" the Plotter Select (;:) command the first time it is sent from the Computer. This condition occurs just after POWER ON or after RESET has been pressed. To avoid this situation, include a character in the program line just before the Plotter Select (;:) command.
- Also load the Driver Routine before plotting.
- Never start a program with PEN in the PEN HOLDER.
- Always end program with P0 so the PEN HOLDER is empty.
- When the PENs are not in use, always replace the protective cap.

4/ Maintenance and Troubleshooting

Care and Maintenance

Your Plotter has been designed to provide trouble-free operation over prolonged periods without any need for specific maintenance. Do not open the Plotter or you may void your warranty. It should be taken to a Radio Shack Service Center for service.

Fuse Replacement

You can safely replace a defective fuse in the Plotter. To replace the fuse, the grey portion (carrier) of the fuseholder must be rotated counter-clockwise to its mechanical stop. Then the fuse carrier with fuse must be removed from the holder and the defective fuse replaced. The fuse and its carrier are then inserted into the holder, "bottomed," and the carrier rotated clockwise in a secured position.

Warning: For protection against fire hazard, replace only with same type and rating of fuse.

Cleaning

Your Plotter uses several sliding surfaces. These are made of stainless steel and plastic such that they are essentially friction free and require no lubricants. These will, however, collect dust which will adversely influence your Plotter's performance. Keep your Plotter as clean as possible by using the dust cover. If necessary, the unit may be wiped clean with a soft cloth using only alcohol or a mild detergent.

Ink On Plotter Surface

Use a clean cloth dipped in a concentrated solution of soap and water; squeeze out excess water and then scrub affected surface. Do not use any aerosol cleaners, such as TV contact cleaner, household wall cleaners, or anything with a solvent; these may damage certain components.

Care of Paper

Paper should be handled at its edges. False pen skipping may occur if the paper has smudges or has been impregnated with oil, grease, perspiration, or other contaminants.

Care of Pens

All pens should be capped when not in use for extended periods of time. The ink will dry out when exposed. Generally, ink flow in a ball point pen can be started by vigorously rubbing the point on a writing surface.

General Notes On Pen/Paper

If a transparency is used for graphics, an etching felt-tipped ink pen must be used. A chemical is included in the ink of this type of pen to produce a permanent trace. In event skipping occurs, clean the transparency with alcohol to remove the contaminants. The trace produced by standard inked pens will rub off when used on a transparency.

Do not use ball point pens on a transparency.

Do not use a felt-tipped pen on paper since the ink will smudge or bleed.

Always replace the protective pen caps when the PENs are not in use.

Troubleshooting

Before attempting to troubleshoot the Plotter, be sure the problem is not caused by improper data source switch setting, broken wires, loose connectors, or incorrect input. Check and ensure that the proper power is available at the wall outlet, and that the power cord is properly matched.

Symptom	Inspection/Adjustment
Plotter completely inactive with power switch ON.	Is AC power available? Is the fuse good?
No Plot function (Remote) but runs in SELF-TEST.	Computer baud at 2400? Are Plotter-to-Computer connectors properly mated? Using proper signal cable?
Pen won't write.	Is Pen bad or out of ink? Is Pen properly installed? Is Pen pressure adequate?
Ragged trace.	Is Pen properly installed? Is Pen carriage secure?

Table 10

5/ Specifications

Physical Dimensions

Height	6 inches (15.2 cm)
Width	15 inches (38 cm)
Depth	10.5 inches (26.6 cm)
Weight	17 pounds (7.7 kg)

Performance

Speed	2.8 inches per second
Step Size	Horizontal .005 inch Vertical .005 inch
Resolution	200 increments per inch

Power Requirements

Input: 115 VAC +/− 10%. 50/60 Hz, single phase, 50 VA max. (Uses .5 ampere SLO-BLO fuse)

Other Features

Operating Temperature	+65 − +95 Degrees F +19 − +34 Degrees C
Storage Temperature	+32 − +160 Degrees F 0 − +71 Degrees C
Home/Office Environment	Relative 20 − 80% Humidity
Surface Area (Platen)	8 1/2 x 11 inch
Plot Size	7 x 9 1/4 inch
Writing Device	Ball Point Pen, selectable colors.
Noise Level	Less than 60 Db at 1 M
Reliability	1200 hrs MTBF

Preprogrammed Capabilities

- Relative and Absolute coordinate addressing.
- Straight line generator with solid or dash line patterns.
- Circle generator.
- Arc generator.
- Character generator.
  - 93 ASCII characters
  - Four rotations
  - Nine sizes
- Marker Symbol Generator
  - Six fixed markers
  - Five sizes
- Soft limits
- Pen changing routine
- Self test

Signal Input Requirements

Mating Connector	DB-25P

EIA RS-232-C Serial Asynchronous

Caution: While the serial port conforms to standard RS-232-C LEVELS, not all standard RS-232-C SIGNALS are brought out; see SIGNAL CONNECTIONS and LEVELS below for details. Failure to ensure proper connection may damage the plotter or other equipment.

Rate	2400 baud, fixed
Allowable cable length	Up to 15 feet
Signal levels:	
TTL: "H" level	2.4 to 5.0V
"L" level	0 to .4 V
RS-232 "H" level	−3 to −25 V
"L" level	+3 to +25 V

Signal Connection and Level

Pin #	Signal	Signal Level
1	↔ Chassis Ground (power)	
2	→ Received Data (from TRS-80)	RS 232
3	← Transmitted Data (to TRS-80)	RS 232
5	← Clear to Send (CTS) from the Plotter	TTL
6	← Data Set Ready (DSR) from the Plotter	TTL
7	↔ Signal Common	
8	Carrier Detect (CD) from the Plotter	TTL
22	Ring Indicator (RI) from the Plotter	TTL

Paper

A smooth, 20 lb., No. 1 (white) sulfite, or better quality, paper may be used to produce normal quality graphics.

Pen

Ball point or ink pens of 2.125 inch length x .375 inch diameter with specially designed retaining features are available in various colors.

Appendix A/ Driver Routines

Before writing your own programs for the Plotter, the Computer must be initialized. Base your programs around the following routines; the routine initializes the Computer, you supply the specific values for the plot.

The routine you use will depend upon the TRS-80 you're using. Where necessary, a brief explanation accompanies the routine.

Model I Driver Routine

```
10 REM PLOTTER DRIVER DEMONSTRATOR FOR MODEL I
20 REM SET MEMORY SIZE AT EXACTLY 65288
30 REM WHEN YOU GO INTO BASICR.
40 GOSUB 150  : REM POKE MODEL 1 SERIAL DRIVER
50 CLEAR 500 : REM STRING AREA
60 PRINT "MULTI-PEN PLOTTER DEMONSTRATION PROGRAM"
70 PRINT ";: NOT NECESSARY "
80 PRINT "HAVE FUN!" : PRINT
90 LINE INPUT "PLOTTER COMMAND STRING: ";A$
100 IF A$= "" THEN 400
110 A$ = ";: " + A$
120 PRINT A$
130 LPRINT A$
140 GOTO 90
150 REM:::SERIAL OUTPUT DRIVER:::MODEL I ONLY:::
160 GOSUB 340
170 IFV=127 THEN M=32592
180 IFV=191 THEN M=-16560
190 IFV=255 THEN M=-176
200 FOR X=M TO (M-1)+54
210 READ Y
220 POKE X,Y
230 NEXT X
240 POKE M+3,V:POKE M+12,V
250 DATA 245,58,134
260 DATA 127
270 DATA 254,1,40,15,62,1,50,134
280 DATA 127
290 DATA 211,232,62,188,211,234,62,170
300 DATA 211,233,241,219,232,203,119,32,250
310 DATA 219,234,203,119,40,244,121,211,235,254
320 DATA 13,192,14,10,219,234,203,127,40,250,219,235,
    24,226
330 RETURN:REM..END DATA..54 BYTES TO POKE
340 P=PEEK(16562)
350 IF P < 128 THEN V = 127 ELSE IF P < 192 THEN V =
    191 ELSE  V = 255
360 POKE 16421,2:POKE 16422,80:POKE 16423,V
370 P=256*V+134:IFP>32767THENP=-(65536-P)
380 POKE P,255
390 RETURN
400 REM:::RESTORE PARALLEL PORT:::MODEL I ONLY:::
410 POKE 16421,6: POKE 16422,141: POKE 16423,5
420 CLS
430 END
```

Model II Driver Routine

```
10 REM MODEL II DEMONSTRATION PROGRAM FOR
   MULTI-PEN PLOTTER
20 REM INITIALIZATION
30 REM MAKE A BUILD FILE NAMED DODRIVE TO DO
   FOLLOWING:
40 REM  SETCOM A=OFF
50 REM SETCOM B=OFF
60 REM SETCOM A=(2400,8,N,2)
70 REM LOAD NEWSUB64
80 REM  BASIC DRIVER -M:61000
90 REM THEN FROM TRSDOS READY TYPE: DO DODRIVE
100 DIM A$(255) : REM 255 IS THE SIZE OF THE PLOTTER
    INPUT BUFFER
110 DEF USR0=&HEF80
120 PRINT " COMPUTER WILL ADD ;: "
130 PRINT : PRINT "HAVE FUN! "
140 PRINT
150 LINE INPUT "PLOTTER COMMAND STRING: ";A$
160 IF A$ = "" GOTO 380: REM TYPE (ENTER) TO QUIT
170 A$ = ";: " + A$ : REM ADD ENABLING COMMAND
180 REM USE BASCOM ROUTINE
190 FOR Z = 1 TO LEN(A$)
200 Z1$ = MID$(A$,Z,1)
210 PRINT Z1$;
220 Z1$ = USR0(Z1$) ' TRANSMIT CHARACTER
230 NEXT Z
240 PRINT
250 REM TRAILING SPACE
260 Z1$ = CHR$(32)
270 Z1$ = USR0(Z1$)
280 REM TRANSMIT RETURN AND LINEFEED
290 Z1$ = CHR$(13)
300 Z1$ = USR0(Z1$)
310 Z1$ = CHR$(10)
320 Z1$ = USR0(Z11$)
330 REM WAIT FOR CARRIAGE RETURN HANDSHAKE FROM
    PLOTTER
340 Z1$ = CHR$(0)
350 Z1$ = USR0(Z1$)
360 IF Z1$ = CHR$(13) THEN 150
370 GOTO 340
380 END
```

Model III Driver Routine

```
10 REM MODEL III DEMONSTRATION PROGRAM FOR PEN PLOTTER
20 REM SET UP DRIVER
30 GOSUB 160
40 CLEAR 1000
50 REM INPUT SAMPLE COMMANDS
60 PRINT ";: NOT NECESSARY," : PRINT
70 LINE INPUT "PLOTTER COMMAND STRING: "; A$
80 PRINT
```

```
90 IF A$= "" THEN 310
100 A$ = ";: " + A$
110 PRINT A$;
120 LPRINT A$
130 H = USR3(0)
140 PRINT
150 GOTO 70
160 REM:::SET UP SERIAL PORT:::
170 DEFUSR1=&H5A
180 POKE 16890,&HFF' SET MODE WAIT
190 BR=10' BAUD RATE 2400
200 POKE 16888,(16*BR)+BR
210 POKE 16889,127
220 X=USR1(0)
230 DEFUSR0=&H006C
240 POKE &H4220,82
250 POKE &H4221,79' RO RS-232 OUT
260 POKE &H4222,80
270 POKE &H4223,82' PR PRINTER
280 X=USR0(0)
290 DEFUSR3=&H0050
300 RETURN
310 REM RESTORE DRIVER ROUTINE
320 DEFUSR2=&H69'  RESTORE DRIVERS
330 X=USR2(0)
340 CLS : END
```

Color Computer Driver Routine

```
10 REM POKE PROGRAM FOR PEN PLOTTER DRIVER
20 CLEAR 500,16255
30 REM POKE MACHINE LANGUAGE INTO RAM
40 FOR I = 1 TO 79
50 READ X
60 POKE 16255+I,X
70 CHECKSUM = CHECKSUM + X
80 NEXT I
90 IF CHECKSUM <> 7362 GOTO 190
100 EXEC 16256
110 PRINT "PEN PLOTTER DRIVER LOADED"
120 GOTO 210  'DEMONSTRATION
130 DATA 52,55,48,141,0,10,191,1,104,134,126,183,1
140 DATA 103,53,183,125,0,111,38,1,57,50,98,52,23,26,
    80,198,2
150 DATA 247,255,32,141,33,95,247,255,32,141,27,198,8,
    52,4
160 DATA 95,68,89,89,247,255,32,141,14,53,4,90
170 DATA 38,240,198,2,247,255,32,141,2,53,151
180 DATA 52,16,142,0,37,48,31,38,252,53,144
190 PRINT "CHECKSUM ERROR-CHECK DATA STATEMENTS"
200 END
210 REM DEMO PROGRAM USING
220 REM DRIVER ROUTINE
230 PRINT":; NOT NEEDED"
240 LINE INPUT "PLOTTER COMMAND STRING: ";A$
```

```
250 IF A$ = "" THEN END
260 A$ = ";: " + A$
270 PRINT#-2,A$
280 GOTO 240
290 END
```

Appendix B/ Using Tandy-Graph

Introduction

The Tandy-Graph Multi-Pen Plotting System is a high level graphics application package. It leads you step-by-step through the creation of sophisticated graphics, requiring no prior experience in plotters, programming, or in your Computer. With simple instructions, you can draw complex line graphs, pie charts, and bar charts.

Tandy-Graph may be used by students, teachers, secretaries, business people, stock brokers, managers, or virtually anyone who needs to see trends, projections, comparisons, analyses of any conceivable kind.

The Tandy-Graph leads you through creating axes, pies, bars, graphs, annotation, pen changing, shading, and many other attractive features.

Tandy-Graph is a BASIC program and is available on diskettes for TRS-80 Model I, Model II, and Model III. You can obtain the version of Tandy-Graph you need for your Computer from the Radio Shack store when you get your Multi-Pen Plotter. Instructions for starting up the program are included in the diskette package; instructions for using the program once it's started up are detailed in this section.

Line Graph

Press (1) on the keyboard to select the Line Graph program. A series of prompts will appear on the screen which you must answer to tell the Computer how you want your plot.

WHAT WOULD YOU LIKE TO TITLE YOUR GRAPH? The title will be placed and centered at the top of the graph. The title can be up to 38 characters in length. The character height is fixed at approximately 5/16″. Type in your title and press (ENTER).

WHAT WOULD YOU LIKE TO LABEL THE X-AXIS? This label will be placed beneath the X-axis. This label can be up to 52 characters in length. The character height is fixed at approximately 1/5th″. Type in the label and press (ENTER).

WHAT WOULD YOU LIKE TO LABEL THE Y-AXIS? This label is positioned to the left of the Y-axis. The title can be up to 38 characters in length. The character height is fixed at approximately 1/5th″. Type in label and press (ENTER).

WOULD YOU LIKE A GRID OVERLAY? This question must be answered YES or NO. If you answer YES to this question, a dotted line will be drawn from each major unit along the X-axis and the Y-axis.

WHAT IS THE RANGE FOR X. (FIRST VALUE, LAST VALUE)? This sets the minimum value and maximum value for an X-coordinate on your line. These are also the first and last values which will be labeled along with the X-axis.

WHAT IS THE RANGE FOR Y. (FIRST VALUE, LAST VALUE)? This sets the minimum value and maximum value for a Y-coordinate on your line. Answer with the two values separated by a comma, then press (ENTER). For example: 0,300 (ENTER).

HOW MANY X UNITS? Enter the number of major units into which you would like to divide the X-axis. Each unit will be labeled along the X-axis.

HOW MANY DIVISIONS FOR EACH X UNIT? Enter the number of divisions into which you would like to divide each unit of the X-axis. The program will mark these divisions with tics along the X-axis.

HOW MANY DIVISIONS FOR EACH Y UNIT? Enter the number of divisions into which you would like to divide each Y unit. Again, the program will mark these divisions with tics along the vertical Y-axis.

WHAT LINE TYPE WOULD YOU LIKE? This lets you select the type of line you would like to use. Select one of the 9 illustrated line types and press the corresponding number. If you plot more than one line on the same graph, you can select a different line type for each line.

WHAT WOULD YOU LIKE TO LABEL YOUR LINE? This allows you to label your line. If a label is not desired, press (SPACEBAR) once, then press (ENTER).

WOULD YOU LIKE TO PUT YOUR LABEL ABOVE OR BELOW YOUR LINE? There are several factors that would compose the decision on where to label the line. Select either "ABOVE" or "BELOW".

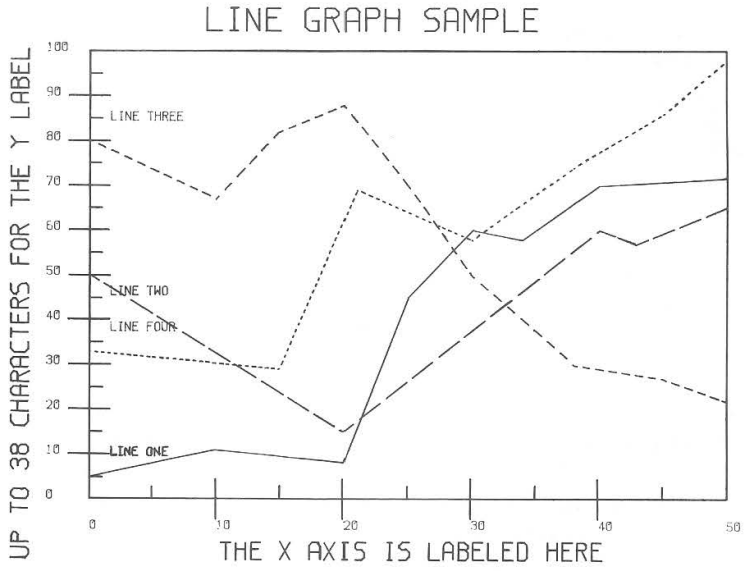


Figure 8 Line Graph

INPUT X, Y COORDINATE. Input your X-coordinate, then a comma (,), followed by the Y-coordinate within the range you have already selected. Press (ENTER). Repeat for all X, Y-coordinates desired. (Maximum 20). When you have finished entering the points, type 999,999 (ENTER). This will allow you to plot, list, or correct the coordinates. Be sure you have entered all the points necessary before typing 999,999. If you enter a wrong value, wait until all points are entered, then correct them.

PRESS P TO PLOT DATA, L TO LIST DATA. To review the coordinates you have entered, press (L). The first 10 (if you entered that many) coordinates will appear on the screen. If the points are accurate, press (ENTER) and the next 10 will appear. Continue this process until all points have been reviewed and the program displays END OF DATA. PRESS P TO PLOT. C TO CORRECT. L TO LIST AGAIN. If all data is correct, press (P) and the Plotter will draw the graph except for the line itself.

If a coordinate is not accurate, press (C) and you will be asked which item number you want to change. The old values will be displayed. Type in the new values and press (ENTER). To verify that the change is accurate, press (L) to list again. When all data is accurate, press (P).

After pressing (P), the data will be sorted. This could take a few seconds. This sorting process is why you are allowed to enter the data in any order. The Plotter will now draw the graph except for the line itself.

Press a key depending on the desired pen color for this line. Press the numbered key of the pen color you select. The line will now be plotted.

WOULD YOU LIKE TO PLOT ANOTHER LINE? If you would like to plot another line on the same graph range as the previous line, type: YES (ENTER).

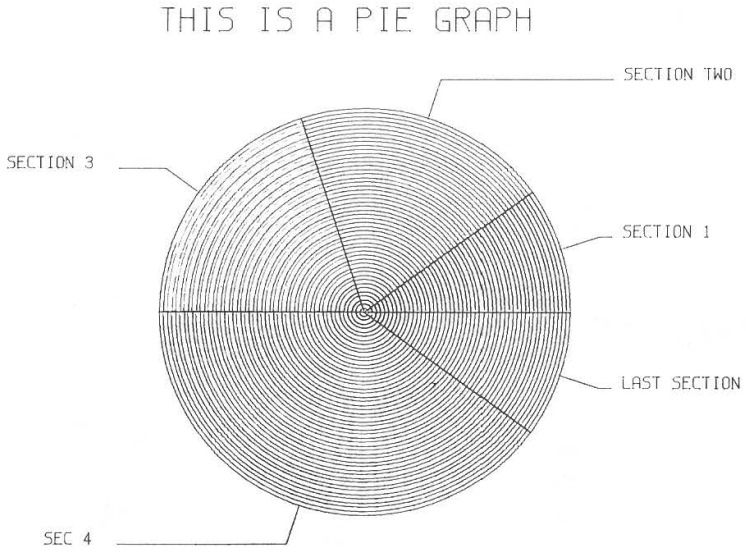
The line type menu will reappear. Follow instructions again starting at WHAT LINE TYPE WOULD YOU LIKE?

If finished, type: NO (ENTER).

Pie Chart

Press (2) on the keyboard to select the Pie Chart Program.

WHAT WOULD YOU LIKE TO TITLE YOUR PIE CHART? The string entered here will be placed at the top of the graph. This string cannot exceed 38 characters.



HOW MANY SECTIONS WILL YOUR CHART CONTAIN? Enter the number of sections you want to divide your pie into (maximum 15).

WHAT IS THE TOTAL NUMBER OF UNITS? Enter the quantity which the whole pie represents.

HOW MANY UNITS WILL SECTION 1 CONTAIN? Enter the number of units Section 1 will contain. The sum of the units for each section must equal the total number of units for the whole pie.

WHAT WOULD YOU LIKE TO LABEL THIS SECTION? Enter any string up to 12 characters. Repeat for all sections.

Note: The program does not ask how many units the last section contains. This provision is added to ensure that the pie is completely subdivided. The program does ask for a label for the last section.

WOULD YOU LIKE TO SHADE YOUR CHART? If NO, the program ends. If YES, press the numbered key which specifies the pen color. Or, if you do not want this section shaded, press (N) and the program will ask if you want the next section shaded. Continue for all sections.

Manual Control

Press (4) to select manual control. A new menu will appear showing the keys to press to allow manual control of the PEN.

Each of the arrow keys may be pressed to move the PEN in that direction. Holding down the key will continually move the PEN. Pressing (P) and (↓) together will cause the PEN to drop to the writing surface. Likewise, pressing (P) (↑) will cause the PEN to rise.

There are two special functions. Pressing (↑) and (←) together will Home the PEN, moving it to the lower left corner of the Plotter. Pressing the (←) and (→) together will initiate a self-test program.

Press (R) to return to the main menu.

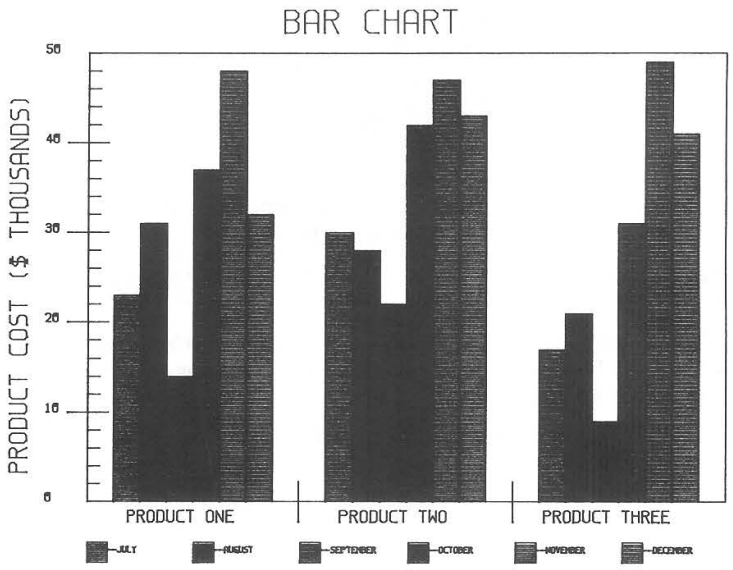
Bar Chart Program

Press (3) to select the Bar Chart Program.

WHAT WOULD YOU LIKE TO TITLE YOUR CHART? The title will be placed and centered at the top of the graph. The title can be any string up to 38 characters in length. The character height is fixed at approximately 5/16". Type in title and press (ENTER).

HOW MANY GROUPS OF BARS WILL YOUR CHART CONTAIN? This determines how many separate sets of bars your chart will contain. Type the number and press (ENTER). 20 is the maximum.

HOW MANY BARS WILL THERE BE PER GROUP? Enter the number of bars you want to compose per group. One is the minimum; six is the maximum. Type the number and press (ENTER).



WOULD YOU LIKE A GRID? If YES is selected, a dotted line will be drawn at each major Y-unit. Type YES (or NO) (ENTER). See Figure 25 for example.

WHAT WOULD YOU LIKE TO LABEL THE Y-AXIS? Enter a string that does not exceed 38 characters. The character height is fixed at approximately 1/5″. This label will be to the left of Y-axis.

WHAT IS THE RANGE FOR Y (FIRST VALUE, LAST VALUE). To input the minimum, maximum value for the range of Y, enter the minimum value, a comma, the maximum value, then (ENTER).

HOW MANY Y-UNITS? Enter the number of major units into which you want to divide your Y-axis.

HOW MANY DIVISIONS FOR EACH Y UNIT? Enter the number of units into which you would like to divide each Y-unit. The divisions will be marked by tics along the Y-axis.

WHAT WOULD YOU LIKE TO LABEL THE #1 BAR IN EACH GROUP? This part defines the legend. When the shading part comes around, it will shade the #1 bar in each group the same color. So, essentially, what you are doing is labeling the first bar in each group with the same label box.

The next bar in each group is labeled in the same manner. After pressing (ENTER), the Plotter will draw the chart except for the bars and group names and then stop. Note that if you select only one bar per group, no label box will be plotted nor will you be asked to label the bar.

WHAT IS THE VALUE OF BAR #1? Enter the height of the bar within the range you have already selected. Continue for all bars of all groups.

WHAT WOULD YOU LIKE TO LABEL THIS GROUP? This allows you to assign a label to each group. Remember, the more groups, the shorter the label must be. Repeat the next group of bars. After all the bars are graphed, the Computer will respond. PRESS KEY ACCORDING TO DESIRED PEN COLOR FOR #1 BAR IN EACH GROUP. Press (ENTER) to continue. The Plotter will shade the first bar in each group and the first label box. If you desire no shading for this set of bars, press (N). The Computer will then say PRESS KEY ACCORDING TO DESIRED PEN COLOR FOR #2 BAR IN EACH GROUP, ETC.

Character Plotting	S	Draws string of letters, selection of four angles and nine heights; choice of 93 characters.
Marker Plotting	M	Draws marker of selected size and type; choice of five sizes and six types.
Circle Plotting	CC	PEN currently on point which is circumference of circle whose center is specified X-Y coordinates relative to point.
Arc Plotting	CA	PEN currently on point of arc of specified +/– degrees whose center is specified X-Y coordinates relative to point.

ASCII Character Set Table

Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char
32	20	40	blank	63	3f	77	?	96	60	140	ˇ
33	21	41	!	64	40	100	@	97	61	141	a
34	22	42	"	65	41	101	A	98	62	142	b
35	23	43	#	66	42	102	B	99	63	142	c
36	24	44	$	67	43	103	C	100	64	144	d
37	25	45	%	68	44	104	D	101	65	145	e
38	26	46	&	69	45	105	E	102	66	146	f
39	27	47	'	70	46	106	F	103	67	147	g
40	28	50	(	71	47	107	G	104	68	150	h
41	29	51	)	72	48	110	H	105	69	151	i
42	2A	52	*	73	49	111	I	106	6A	152	j
43	2B	53	+	74	4A	112	J	107	6B	153	k
44	2C	54	,	75	4B	113	K	108	6C	154	l
45	2D	55	—	76	4C	114	L	109	6D	155	m
46	2E	56	.	77	4D	115	M	110	6E	156	n
47	2F	57	/	78	4E	116	N	111	6F	157	o
48	30	60	0	79	4F	117	O	112	70	160	p
49	31	61	1	80	50	120	P	113	71	161	q
50	32	62	2	81	51	121	Q	114	72	162	r
51	33	63	3	82	52	122	R	115	73	163	s
52	34	64	4	83	53	123	S	116	74	164	t
53	35	65	5	84	54	124	T	117	75	165	u
54	36	66	6	85	55	125	U	118	76	166	v
55	37	67	7	86	56	126	V	119	77	167	w
56	38	70	8	87	57	127	W	120	78	170	x
57	39	71	9	88	58	130	X	121	79	171	y
58	3A	72	:	89	59	131	Y	122	7A	172	z
59	3B	73	;	90	5A	132	Z	123	7B	173	{
60	3C	74	<	91	5B	133	⌂	124	7C	174	‖
61	3D	75	=	92	5C	134	Ç	125	7D	175	}
62	3E	76	>	93	5D	135	ü	126	7E	176	~

ASCII Code/Rotation

Code #	Rotation
1	none
2	90 degrees
3	180 degrees
4	270 degrees

ASCII Code/Height

Code #	Height (inches)
1	.070 inch
2	.105 inch
3	.14 inch
4	.21 inch
5	.28 inch
6	.42 inch
7	.56 inch
8	.85 inch
9	1.12 inch

Marker Symbol

Code #	Marker
0	+
1	x
2	□
3	○
4	△
5	[X]

Symbol Size

Code #	Marker Size
1	.07 inch
2	.14 inch
3	.28 inch
4	.56 inch
5	1.12 inch

Appendix D/Theory of Operation

General

This Plotter has a built-in 8-bit microprocessor. It also contains a 1K Random Access Memory (RAM) and a 6K Read Only Memory (ROM). The ROM is programmed at the factory, it contains line generator, character and symbol generation, and the plotter operating routine.

Plotting Theory

General

A digital Plotter requires pulses from a digital data source to create a graphic display. To accomplish this, the plotting surface is identified by three basic axes: the X axis, normally the paper, BEAM, or horizontal axes; the Y axis, normally the PEN or vertical axis; and finally, the Z axis which corresponds to the raising and lowering of the PEN to mark the paper. Inputs are then generated in positive and negative directions to the designated X and Y and Z axes.

Plotter Fundamentals

A review of the properties of the rectangular Cartesian coordinate system are helpful in gaining an understanding of plotting theory. Two axes, customarily designated X and Y, are constructed perpendicular to each other intersecting at the origin. Positive quantities are measured along the X-axis in the direction to the right of the origin, and negative quantities are measured in the opposite direction. Similarly, for the Y-axis, positive quantities lie above the origin and negative quantities below.

Thus, any two distances, X and Y, describe the location of any position with respect to the origin.

Absolute Vector Pairs

In an absolute system of coordinates, the area to be plotted can be visualized as the upper right quadrant of the cartesian system and any point on the field would have a corresponding set of vector pairs with respect to the lower left corner.

This concept is incorporated in the Plotter and identified as Absolute Pen Positioning.

Relative Vector Pairs

In a relative system of coordinates, the area to be plotted can also be visualized as a gridded field, just as in an absolute system. But, in a relative system of coordinates, each successive set of vector pairs is relative to the last. This concept is also incorporated in your plotter's firmware and is identified as Relative Pen Positioning and is covered later in this section.

The Incremental Path

The term, incremental, comes from the method used to create the graphics display. The line, circle, graph or chart is drawn by moving the pen carriage or BEAM an incremental (step) distance in response to each byte received at the input connector. These input pulses are processed by circuitry in the plotter and then applied to a motor. A "stepper" motor, as it is commonly called, requires a specific number of input pulses to rotate the motor shaft 360 degrees. Stepping pulses for these motors range from 100 to 5000 steps per second depending on its design and the drive method used to cause motor stepping action.

Assume that the X and/or Y values may be received for both axes simultaneously, the distance of the resultant vector step is equal to the square root of (2 times the step size) squared SQR(2*(.005^2)) inch = .007. Therefore, with only two stepper motors, the PEN and BEAM combinations can be moved in 8 specific directions. It can be easily shown that by using 8 directions, a line at any angle can be approximated more precisely than if only the four axial moves were used. It is the function of the Plotter Computer to calculate the optimum sequence of moves for any given line slope.

Plotter Data Functions

Your Plotter may be regarded as an Information Manager. As such, it receives directives and data from you via the Computer. It alters, counts, calculates, controls, and converts the data from an electrical to a mechanical form which drives a writing device in tiny (.005 inch) straight lines to produce graphics.

Input-Output and UAR/T

A signal cable connects the Computer and the Plotter together. Two lines within the cable pass virtually all of the communications between these units. Information is exchanged in a full duplex communications mode. Digital information containing plot commands and data from the Computer is received in a serial bit stream at 2400 baud. These bits are received at RS-232 voltage levels and then converted to TTL levels by a signal level converter. After conversion to TTL levels, the serial bit stream is converted to parallel 7-bit ASCII code format, by the clock synchronized universal asynchronous receiver/transmitter (UAR/T) for use by the Plotter's internal microcomputer.

Master Clock

The clock for the Plotter is a crystal controlled oscillator. Its fundamental frequency is 4.9152 MHz. This frequency is divided at various points within the plotter in order to provide the proper timing to synchronize the various functions in the plotter's computer and the UAR/T. These include the transfer and processing of the input information, the conversion from serial to parallel and the converse plus the management of the mechanical actions of the plotter.

Microprocessor

The Plotter's microprocessor is an 8-bit, single chip (Z80) CPU. It performs all arithmetic operations and calculations within the machine. The CPU is supported by a Z80 CTC which keeps up with system timing, and processes interrupts to the CPU. These two chips are the heart of the internal computing system. These components and the rest of the information processing system communicate via two buses (i.e., an address bus and a data bus).

The CTC receives the incoming clock signal from master clock and provides timing for the rest of the data processing system. The CTC also processes incoming interrupts and assigns priorities to them. If the CPU is executing the motor timing function and a data available interrupt is inserted, then the CTC will cause the motor timing routine to wait until the data available interrupt has been satisfied. The internal microprocessor operates much faster than the motors, thus the interrupt is not apparent to the operator. The interrupts, in order of priority, are: 1) data available; 2) motor timing.

Data can be input to the plotter regardless of control panel status. Incoming data is input to the data buffer in the foreground while control panel operations take place in the background.

Buffer size is limited to 256 bytes. The bidirectional buffer shares internal data with the CPU and CTC and acts as an output buffer to the rest of the system; it also alerts the CPU. IF an interrupt is from incoming data and if valid, it enables the proper components to act accordingly.

The first data the CPU must receive is the Plotter Select code (;:). All incoming data is always scanned but nothing happens until the first Plotter Select command is received.

The address bus is controlled by the CPU through some decoding circuitry. The decoders flag the particular component being addressed. This bus interconnects the memories and the I/O circuitry.

RAM and EPROM

Included in the processing system are 1K of Random Access Memory (RAM) and 6K of Read Only Memories. The ROMS contain the programming necessary for line generation, character and symbol generation, and the system operating routines. When commanded, the routine actually looks up the vectors to form the desired symbol and executes the command.

Motor Drivers and PEN Lift

After the data input to the Plotter has been processed and the desired graphics/vectors to be plotted have been calculated, the data is strobed out to a latch/driver chip. This chip turns the stepper motor driver transistors on in the proper sequence to produce the desired X-Y movement of the Plotter's PEN. The PEN axis (Z-Up/Down) is similarly controlled by the Computer.

The motor drivers and the Pen solenoid have a time out (remove power) feature. This feature removes power from the Pen solenoid and the stepper motors after some three seconds duration.

Stepper Motors

Stepper motors are specifically designed to rotate from pole to pole on sequentially energized field windings. The motor responds precisely to the Computer's code and rotates in discrete increments as far and as rapidly as directed with no complicated feedback loop. The Computer must, however, continually count the exact number of net steps executed by each stepper motor so that the precise PEN location is known at all times. The stepper motor on the Plotter has 50 poles. With appropriate techniques, the motor is driven at 400 steps per revolution.

SERVICE POLICY

Radio Shack's nationwide network of service facilities provides quick, convenient, and reliable repair services for all of its computer products, in most instances. Warranty service will be performed in accordance with Radio Shack's Limited Warranty. Non-warranty service will be provided at reasonable parts and labor costs.

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