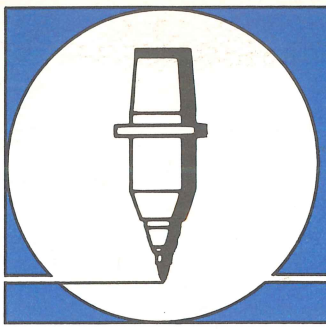
229-6



PLOTTER NOTES

NUMBER 6

INTERFACING AND HANDSHAKING GUIDE

What's Inside This Document

The procedure required to interface a peripheral device to a computer is a multistep process. This application note thoroughly explains the underlying concepts as well as the instructions used in this process and supplements the material contained in the operating and programming manuals for HP's EIA RS-232-C/CCITT V.24 plotters. This note emphasizes how to determine and set up communication and handshake protocol.

Who Should Read This and How

This document should prove useful to new owners of HP plotters as well as more experienced users. Depending on your knowledge of handshaking protocol, you may want to read this note from start to finish or to read only selected sections. Use the notes and graphics in the margins to find information quickly or to decide if you need to read that section. Because there are slight differences in the controls and instruction sets for each HP plotter, the appropriate operating manual for your plotter should be used in conjunction with this application note when interfacing your plotter.

NOTE: All information in this plotter note applies equally to RS-232-C and CCITT V.24 interfaces except for the pin assignments as noted in the appendix. For simplicity, the term RS-232-C has been used to refer to both interfaces. □

AN OVERVIEW OF INTERFACING

Before connecting one of HP's serial RS-232-C graphics devices to a computer, it is helpful to understand what an interface does and why it is necessary. Ideally, all graphics peripherals and computers would conform to some standard that specified all the characteristics of their input/output connections, making all such devices plug-to-plug compatible. Unfortunately, at the present time, no such standard exists. In the case of the serial RS-232-C interface, the EIA standards address only the mechanical and electrical characteristics and the functions of signals; other characteristics are not addressed. As a result, compliance with the RS-232-C standard is not a guarantee of compatibility between two devices. In actuality, there are four areas of compatibility that must be satisfied in order to successfully interface a graphics device and a computer. They are:

- Mechanical compatibility,
- Electrical compatibility,
- Data compatibility, and
- Communication compatibility.

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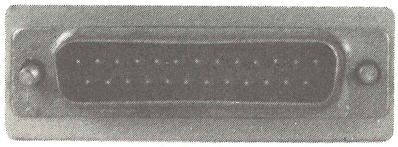
Let's take a brief look at the first three areas before dealing in depth with communication compatibility.

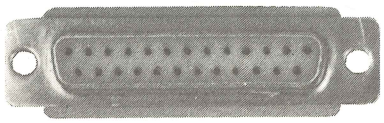
Mechanical Compatibility

RS-232-C mechanical compatibility implies the use of a standard 25-pin connector. The EIA standard defines 25 wires and their respective signal functions; these are the wires that may be used to interface a peripheral device and a computer or modem and, in some cases, a data terminal. On HP plotters a maximum of nine lines have been connected to the plotter's internal circuitry. Refer to your operating and programming manual and the appendix of this note for information on the signal designation and direction.

RS-232-C Connectors



Male Connector



Female Connector

Electrical Compatibility

Data is passed between devices over the data lines using two voltage levels to represent the two possible states (1 or 0) of a binary digit or bit. The voltage levels must be compatible for the two devices. RS-232-C standards specify that voltage levels between +3 V and +25 V on data lines be recognized as 0 or "space" and on control lines as ON. Voltage levels between −3 V and −25 V must be recognized as 1 or "mark" for data lines and as OFF for control lines.

Data Compatibility

Once an interface has made the computer and its graphics device mechanically and electrically compatible, they are capable of exchanging messages in the form of electrical signals. But in order for these messages to be understood and executed, certain conventions must be followed regarding the formatting of the data to be exchanged. For internal communication, devices may use any data format, but each will input and output data in one of two standard representations, EBCDIC or ASCII (American Standard Code for Information Interchange).

All HP plotters utilize the ASCII code; as a result, they are compatible with a wide variety of devices. There are two important characteristics to be considered in determining compatibility when transferring data between the computer and plotter — the number of bits per character and the format of those bits. ASCII characters are coded in seven bits, with an eighth bit to be used as a parity, or error-checking, bit. While the parity bit may not be active, it still must be included as the eighth bit of each character. This code allows 128 unique bit patterns for character representation.

The following table shows the binary code for the uppercase characters A through C and the decimal equivalent of their seven low-order bits. The lowercase p in the binary code represents the required eighth bit, the parity bit which may have the value 0 or 1. You will use decimal equivalents of ASCII characters to specify some parameters of the plotter commands which establish communication between the plotter and the computer.

ASCII Character	Binary Code	Decimal Equivalent of Low-Order Seven Bits
A	p1000001	65
B	p1000010	66
C	p1000011	67

Asynchronous Transmission and Stop Bits

Data is transmitted asynchronously across the signal lines by means of these eight-bit characters. Asynchronous transmission means the data transfer may be initiated at any time, and each character sent need not have any time relationship to any other character. In order for the receiving device to distinguish the starting and ending point of each character, each eight-bit group must be preceded by a "start" bit and followed by one or two "stop" bits. In most cases, plotters verify and generate a single stop bit. Two stop bits are generated and verified by HP plotters if their baud rate setting is less than or equal to 110. Switches or jumpers can be used on some plotters so that two stop bits are also generated at settings above 110.

COMMUNICATION COMPATIBILITY

Overview

Both computers and their peripheral devices have a wide range of operating speeds. The graphics peripherals are typically slower in their ability to execute instructions than computers are in their ability to generate them, necessitating the design of a system to ensure the efficient transmission and receipt of data without loss. Providing this communication compatibility is the fourth and final step required to interface your plotter with your computer.

There are four factors to consider in establishing communication compatibility between two devices — baud rate, input buffer characteristics, communication protocol, and handshake protocol.

Baud Rate

The first timing requirement is to match the data transmission speeds of the interfacing devices. This is done by setting the baud or transmission rates of the computer and plotter equal. The baud rate is approximately equal to the number of bits transmitted per second. This can be translated into an approximate number of characters per second, since each character is 10 bits long (eight-bit code plus one start and one stop bit). At 300 baud, a maximum of 30 characters per second may be transmitted. It is crucial that the device receiving data be prepared to interpret the eight-bit characters at the same rate at which they are sent. Failure to do so will result in garbled data. The baud rate selection dial or switches are located on the plotter's rear panel.

Baud Rates for HP Plotters

HP RS-232-C plotters receive and transmit data at the standard baud rates shown in the following table.

Model	Switch-Selectable Baud Rates
7220, 7221, 7240	75, 110, 150, 200, 300, 600, 1200, 2400
7470	*75, 110, 150, 200, 300, 600, 1200, 2400, 4800, 9600
7580	110, 150, 300, 600, 1200, 2400, 4800, 9600

*The 7470 can be operated at intermediate baud rates if an external clock is connected to pin 17 of the connector (DD).

Input Buffer

All HP plotters with an RS-232-C interface use an input buffer to store data until the plotter can process it. Because the plotter has an input buffer, the computer can send large blocks of data at high speeds, a more efficient method than sending a few characters at a time. Moreover, the buffer uncouples the plotter's data execution rate from the data transmission rate of the terminal or computer.

What Gets Buffered

All plotter instructions except device control instructions are placed in the buffer on a first-in, first-out basis; device control instructions, which begin with the escape character followed by the character "." are not placed in the buffer but instead are processed immediately. Plotting instructions from the computer are held in the buffer, if necessary, until the plotter is free to process and execute them. Buffer sizes for HP RS-232-C plotters are shown below.

Buffer Size

Model	Buffer Size
7220C/T	928 bytes, additional 2048 byte RAM optional
7221C/T	1110 bytes, additional 2048 byte RAM optional
7240	1236 bytes
7470	255 bytes
7580	1024 bytes

An Introduction to Communication Protocol

HP plotters are designed to appear as a simple teletype terminal to a computer. Any plotter responses are formatted as though a person typed them on a terminal. Every computer requires information to be sent to it in a particular manner. For instance, the computer may need to be told that data is coming and that the end of data has been reached. There are six parameters which may be specified so that data sent as a result of plotter output commands can be understood by the computer.

Instructions Used

These parameters are specified in the set output mode instruction, ESC . M, and the set extended output and handshake mode instruction, ESC . N. These instructions and their parameters will be discussed in detail later, in the section titled Matching Your Computer's Communication Protocol. It is good programming practice to place these instructions ahead of the instructions which establish a handshake. When the ESC . H instruction, discussed later under the enquire/acknowledge handshake, is used to establish a handshake, any ESC . M or ESC . N command must be executed before any handshake enable character is sent to a plotter.

An Introduction to Handshaking Protocol

In order to prevent loss of data due to buffer overflow, the computer and plotter must communicate about the availability of buffer space in the plotter. This process is called "handshaking." HP plotters have the ability to implement several different handshakes. Therefore, they can interface with many types of equipment from different manufacturers, resulting in greater flexibility in the assembling of computer graphics systems. An efficient handshake will optimize computer/peripheral communication while preventing data loss. There are four basic types of handshakes that can be used by HP graphics devices:

The Four Handshakes

- **Hardwire handshake** — uses a physical wire, pin 20 of the RS-232-C connector, to control handshaking. It can be used if the computer and the plotter are directly connected, without a modem, and the computer system can or does monitor pin 20 (CD, Data Terminal Ready).
- **Xon-Xoff handshake** — is initiated by the peripheral device, e.g., a plotter. It can be used if the computer system supports an Xon-Xoff protocol, which means that control characters are sent from the plotter to the computer to indicate when the plotter's buffer is full and when it again has room for more data.
- **Enquire/acknowledge handshake** — is initiated by the computer system software in specific cases where it uses the two ASCII characters ENQ and ACK as the handshake enable character and handshake response string. The same instructions are used to establish this handshake as are used to establish the first type of software handshake described below.
- **Software/checking handshake** — is managed by the applications programmer. It can be used on almost any computer system, but it must be used if the system cannot implement any of the other three handshaking methods. One type of software handshake is a "generic" enquire/acknowledge handshake which asks if there is room in the plotter for a block of data; the computer sends that block only after receiving an acknowledgement. Any character(s), not just ENQ and ACK, may be specified as the handshake enable character and the handshake response string. The other type of software handshake repeatedly asks how many bytes are available in the buffer, and sends the data when the space available is larger than the block to be sent. This second method can degrade system performance in a multi-user environment because it increases the load on the I/O system.

MATCHING YOUR COMPUTER'S COMMUNICATION PROTOCOL

Overview

Communication protocol is independent of the handshake chosen. Its primary purpose is to assure data is sent from the plotter in a format that the computer can understand. The two instructions used to establish this protocol are ESC . M and ESC . N. This section contains a general description of the six parameters affecting output which may be specified in one of these instructions, followed by a discussion of each instruction, its syntax, and some examples.

Parameters for Plotter Output

Turnaround Delay

The turnaround delay is the length of time the plotter will wait after receiving a computer request and the output trigger character, if any, before it responds. The purpose of this time delay is to postpone the plotter's transmission of requested data until the computer is ready to receive and process it. Systems may require either a turnaround delay or a trigger character or both.

Output Trigger Character

The output trigger character, when used, is the last character output by the computer when making a request of a graphics peripheral. Defining this character tells the plotter, "Don't respond to my request until you receive this trigger character." This character is often a nonprinting character, or a printing character such as "?" or ">". On DEC systems, line feed is often used as the output trigger character.

Echo-Terminate Character

Echoing is commonly found in full-duplex systems. Use of the echo-terminate parameter tells the plotter that the computer will echo all responses, and that this echoed data should be ignored (the plotter's data buffer should be closed) until an echo-

terminate character is received. When the plotter receives the echo-terminate character, it reopens the data buffer to receive graphics data from the computer. Computers often append the line feed character (decimal equivalent 10) to the plotter's response as the echo terminator. If the computer echoes the plotter's response without appending a character, then the plotter's output terminator (which is either a carriage return or a different character which has been specified by the user) should be used as the echo terminator. If the computer does not echo the peripheral's response, this parameter must be specified as zero (equivalent to null) or must be omitted.

Output Terminator

The output terminator is a one- or two-character terminator that the computer requires the plotter to send at the end of each response to a data request. The output terminator tells the computer, "This completes my transmission." Often computers expect the carriage return character (decimal equivalent 13) as the plotter's output terminator. The plotter sends a carriage return as the output terminator unless a different character has been specified by an ESC . M command.

Output Initiator Character

The output initiator character can only be specified for the 7470 plotter. It is a one-character initiator that is sent by the plotter at the beginning of a string. The output initiator tells the computer, "This starts my transmission." Some computers expect the start-of-text character (decimal equivalent 2) as the plotter's output initiator.

Intercharacter Delay

Some computers cannot process data as fast as the plotter can transmit it, especially at high baud rates, due to limited buffering in the I/O port. This can be compensated for by delaying each transmission from the plotter a period of time as specified by the intercharacter delay parameter. This intercharacter delay is added to the turnaround delay (if one has been specified) before the first character is sent by the plotter, and is also inserted before each subsequent character in a string being sent to the computer.

Instructions Used to Set Communication Protocol

ESC . M

There are two device control instructions used to establish communication protocol. The set output mode instruction, ESC . M, is used to inform the plotter what turnaround delay, output trigger character, echo-terminate character, output terminator, and, on the 7470, output initiator to use. This instruction has the following form:

ESC[1] . M turnaround delay[2]; output trigger character[3]; echo-terminate character[3]; output terminator[4]; output initiator (7470 only)[3]:

The instruction which specifies a 100-millisecond turnaround delay, DC1 as the trigger character, line feed as the echo terminator, and carriage return as the output terminator is:

ESC . M 100; 17; 10; 13:

The final parameter, 13, could have been omitted by placing the colon directly after the 10 and the results would be the same, because carriage return is the default output terminator sent by the plotter unless an ESC . M command specifies a different character or characters. Note that for the last three parameters, the decimal equivalent of the ASCII character is used to specify a parameter.

[1]Text in reverse type represents a single ASCII character.

[2]An integer, base 10, without a decimal point.

[3]The integer decimal equivalent of an ASCII character.

[4]The integer decimal equivalent(s) of one or two ASCII characters, separated by a semicolon.

ESC . N

The set extended output and handshake mode instruction, ESC . N, is used to establish any intercharacter delay. This command has the following form:

ESC . N intercharacter delay[1] ; Xoff trigger character(s) or immediate response string[2] :

When a hardwire handshake or a software checking handshake is being established, the intercharacter delay is the only parameter of the ESC . N command. For Xon-Xoff handshakes and handshakes of the enquire/acknowledge type, additional parameters will follow the turnaround delay. Complete information on the second parameter is found in the descriptions of the corresponding handshakes.

The following ESC . N command will set up a 10-millisecond intercharacter delay when a hardwire handshake or software checking handshake is in effect:

ESC . N 10 :

Further examples of these instructions in conjunction with different handshakes appear later in this application note and in the individual plotter manuals. Refer to your plotter manual for information on parameter ranges, default values, and omitting parameters.

Determining Parameter Values to Match Your System

A Test You Can Perform

If you are not sure what parameters your system needs for output trigger, echo terminate, and output terminator characters, running the following FORTRAN program on your computer may help you identify these parameters. You should direct the output of this program to the output port to which the plotter will be connected. Replace the plotter with a standard ASCII CRT terminal. Set the terminal (and the plotter) to the mode which matches your system, i.e., full- or half-duplex, echo on or off, and odd, even, or no parity. If the system does not echo transmissions, the proper value for the echo terminator, the third parameter of the ESC . M instruction, is zero. Set the baud rate on both the plotter and the terminal to the fastest rate allowed by the plotter and computer. Disable any automatic line feed capability in the terminal. Later in this test you will want to place the terminal in "display functions" mode, if possible. In that mode, a corresponding symbol is displayed for each ASCII control character received. Most HP terminals, Tektronix terminals, and some other CRT terminals have that capability. For now, be sure the terminal is not in display functions mode.

Setting Up the Test

Assign the FORTRAN unit numbers 10 and 11, specified in the WRITE and READ statements of the following program, to the output port to which the terminal is connected. If your system does not use the standard FORTRAN format specifier "1H+" to suppress the line feed before output, consult your FORTRAN programming documentation, and substitute the FORMAT specifier which will suppress line feeds for the "1H+".

[1]An integer, base 10, without a decimal point.

[2]The integer decimal equivalent(s) of a string of from 1 to 10 ASCII characters, separated by semicolons.

```
      PROGRAM IOTEST
      WRITE(10,9000)
9000  FORMAT(1H+,13HABCDEFGHIJKLM)
      WRITE(10,9001)
9001  FORMAT(1H+,13HNOPQRSTUVWXYZ)
C
C THESE 2 LOOPS ARE TO CAUSE A DELAY BETWEEN THE OUTPUT
C OF THE 26 CHARACTERS AND THE TRIGGER CHARACTER FOR THE
C READ OF THE INTEGER AND A DELAY BETWEEN ENTERING THE
C INTEGER AND THE END OF THE PROGRAM.
C
      X=1.0
      DO 100 I=1,32000
         X=X+2.0-3.0*2.0-8.0
100   CONTINUE
      READ(11,9002) IANS
9002  FORMAT(I1)
      DO 200 I=1,32000
         X=X+2.0-3.0*2.0-8.0
200   CONTINUE
      STOP
      END
```

What's in the DO Loops

The two DO loops are used to create a noticeable time delay before and after the READ operation so you will be able to observe the action of the terminal's cursor. Faster systems may require more delay; simply increase the number of times the loop is executed. When the program runs, the WRITE statements should overprint on the same line, and the program should stop, waiting for your response. If the WRITE statements print on separate lines, check to see if you have used the proper format specifier for suppressing line feeds in the FORMAT statement, and be sure your terminal was not in display functions mode and that auto line feed was disabled.

Testing for the Output Trigger Character

Now set your terminal to display functions mode and run the program again. To check which character you should use for a trigger character, note any character displayed after the Z while the program pauses for your input. Often it is a non-printing control character, but the question mark, a colon, or some other prompt is sometimes used. You should specify the displayed character as the output trigger character by sending its decimal equivalent as the second parameter of the ESC . M command.

If your terminal does not have display functions mode, carefully observe what happens to the terminal's cursor while the text is written and where it is when it is waiting for your response. If the cursor stops at the end of the line of printed characters, probably no trigger character is required. If the cursor is on the line immediately below the characters, a line feed is being sent. Note whether it appears to be printed together with the line of printed characters, or if there appears to be some delay after the last character is printed before the line feed occurs. If a delay is evident, the line feed is being sent as part of the READ operation. Unless your system documentation can provide other information, it is probably safe to assume that a line feed character is being sent as, and should be specified as, the output trigger character.

Testing for the Echo-Terminate Character

The next step will determine what you should use as the echo-terminate character. If you are in half-duplex mode or your system can operate with no echo, enter zero as the parameter, signifying no echo terminator. If you are in full-duplex mode with

echo enabled, observe what happens to the cursor after you type a one-digit number followed by a carriage return.

For terminals with display functions mode enabled, if a line feed character or some other character is displayed following the carriage return, that character is being appended to the echoed response and should be specified as the echo terminator. Otherwise, specify the carriage return character as both the echo terminator and output terminator.

For terminals without display functions mode, if the cursor simply returns to the left margin on the same line, your system does not append a line feed to the echoed response, and you will need to specify the carriage return as the echo terminator. If the cursor returns to the left margin of the next line down, a line feed is being appended to the end of the echo, and should be used as the echo-terminate character.

Echo Terminator Values for Certain Systems

The DEC PDP-11 systems with RT-11 and RSTS/E and VAX VMS operating systems append a line feed to the echo, while the DEC RSX-11M operating system does not. Most other systems also append a line feed. If you change the plotter's output terminator (using ESC . M) on a system which does not append a line feed, specify the same character as both the output terminator and the echo terminator.

HANDSHAKING: A DETAILED DESCRIPTION

Who Should Read What

The remainder of this note concerns the four handshakes implemented on Hewlett-Packard plotters. The next section contains guidelines for selecting a handshake. Skip that section if you already know which type of handshake you will use. Each of the four sections about a particular handshake includes definitions of the terms associated with that handshake, an explanation of the instructions used, and at least one example. You may want to read only those sections about handshakes which you are considering for your system or application. To help you identify pertinent paragraphs, symbols for the various handshakes have been placed in the left margin of paragraphs concerning a particular handshake. The four symbols are:

for hardwire handshake

for Xon-Xoff handshake

for enquire/acknowledge handshake

for software checking handshake

Guidelines for Selecting a Handshake Method

But how does one know which handshake is best for a specific installation? The ideal handshake minimizes I/O transactions while keeping the plotter's data buffer supplied with data. The communication characteristics and capabilities of the host computer dictate which of the four handshaking methods are possible and will be most efficient. Device control instructions from the plotter's instruction set are used to tell the plotter which handshake is to be used so that the plotter conforms to the computer's requirements. **A thorough understanding of the computer's communication**

characteristics is necessary in order to make the best decision on the type of handshake.

If you do not already know which is the best handshake to use, you should first consult your systems manual or the installation manual for your graphics software. Most graphics software designed for use with Hewlett-Packard RS-232-C plotters contains the instructions necessary to set up a handshake. You may need to fill in parameters suitable to your system which will be used in subroutine calls. The information you need to do this is found in the installation guides for the software. If you are not using a commercial software package, your system manual may tell you whether your system supports Xon-Xoff protocol, or hardwire handshake. If no recommendations can be found in your documentation, the following information should help you choose an efficient handshake.

Plotters Hardwired to the Computer

The operating environment of your computer affects the number of choices you have; your plotter operates in either a hardwire or remote environment. In a hardwire environment, there is no intermediate hardware between the plotter and computer; a cable goes directly from plotter to computer. The hardwire handshake can only be used in this environment. It is a very efficient handshake. Sometimes the term automatic handshake is used in computer manuals for this type of handshake.

Plotters in a Remote Environment

In a remote environment, the plotter is connected to the computer via a modem. If your plotter communicates with the computer via a modem, you cannot use a hardwire handshake and must choose between Xon-Xoff, enquire/acknowledge, or software checking handshake. It could be argued that all three of these handshakes are software handshakes because they do not involve hardware. The Xon-Xoff handshake and some enquire/acknowledge handshakes are implemented in the operating system or device driver. The other handshakes are implemented in the graphics program.

Of the two types of software checking handshakes described briefly earlier in this note, the second method, which repeatedly checks the buffer space available, is the least efficient handshake, but it has one advantage. It works on any computer and requires no knowledge of your operating system or computer's characteristics. It may be the one you want to use at least temporarily to get a program running. This handshake, which uses the ESC . B instruction, is described later in this document and in your plotter manual under software checking handshake.

If efficiency is important, either because you are in a multi-user environment or want to minimize I/O transactions, and you cannot use a hardwire handshake, you will want to use either Xon-Xoff or the enquire/acknowledge type of handshake. If your system supports Xon-Xoff protocol, you should probably use that handshake. The handshake is efficient when sending either variable- or fixed-length records. Refer to the section on Xon-Xoff handshaking later in this document to learn which parameters and instructions are necessary, and then refer to your plotter manual for a detailed description of the parameters. A list of computers and operating systems on which the Xon-Xoff handshake has been successfully used is found in the Appendix.

A Test for Xon-Xoff Capability

You may easily test your system for Xon-Xoff support by printing a long program listing or other text to a terminal plugged into the RS-232-C connector you plan to attach to your plotter. While information is printing on your display, send the ASCII character DC3 (Xoff) to the computer. On many terminals, this is done by pressing and holding the terminal's CONTROL key (sometimes labeled "CNTL" or

"CTRL") and then pressing the "S" key. If printing immediately stops, send the character DC1 (Xon), often sent by pressing and holding the CONTROL key and then pressing the "Q" key. The printing should resume. If you can stop and start printing in this manner, you can probably use the Xon-Xoff handshake.

The only handshake we have not yet discussed in this section is the enquire/acknowledge handshake. This handshake can be implemented in either the application program or the device driver. In either case, one of two mutually exclusive instructions, ESC . H or ESC . I, must be sent to the plotter to specify the enquire and acknowledge characters. Refer to the detailed description of enquire/acknowledge handshake for information on these two instructions and which one to choose. The enquire/acknowledge handshake is quite efficient and can be implemented on any system, provided the communication needs of that system have been taken into account. Since the block size parameter must be set to accommodate the largest record, use with variable-length records where there is a wide range of record lengths is somewhat inefficient.

Hardwire Handshake

As the name implies, the hardwire handshake takes place in the hardware rather than the firmware or software. The plotter controls the data exchange sequence by setting the electrical voltage on pin 20 of the connector (CD line) to the computer in order to signal the computer when to send another block of data. If there is enough room in the plotter's buffer to store another block of data, the plotter sets the Data Terminal Ready (CD) line to a high state. If there is insufficient space, it sets the line low. By monitoring this line, the computer knows when it can or cannot safely transmit another block of data.

Set Plotter Configuration, ESC . @

The hardwire handshake can be implemented on all Hewlett-Packard RS-232-C plotters except the 7221A. This is done by setting the Data Termial Ready line control using the set plotter configuration command, ESC . @. Since there are slight differences in the implementation of the ESC . @ command on each plotter, refer to your plotter's documentation when using this command.

Switch-Selectable

In some cases, an ESC . @ command need not be sent to enable hardwire handshake. On the HP 7470, hardwire handshake is enabled at power-on. Also, on plotters with a MODEM/HARDWIRE switch, hardwire handshake is enabled at power-on when the switch is in the hardwire position.

Block Size

The block size should be specified as the largest block of data that the computer will send to the plotter at one time. This parameter is closely tied to the output characteristics of the computer and is frequently set equal to the line length of the system's printer. The block size is set by the first parameter of an ESC . H or ESC . I command. If no parameter is included, the plotter will assume a block size of 80 bytes.

Xon-Xoff Handshake

The Xon-Xoff handshake is becoming more common and is the preferred handshake method for many minicomputer systems and some larger systems. Conceptually, it is easy to understand and relatively transparent to the user. It is probably the most efficient handshake that can be used in a remote environment.

With the Xon-Xoff handshake, the plotter controls the data exchange sequence by telling the computer when it has room in its buffer for data and when to shut off the

flow of data. The plotter uses buffer threshold indicators, an Xon trigger character, and an Xoff trigger character to prevent buffer overflow by sending the Xoff trigger character when the Xoff threshold is reached.

Parameters Used in an Xon-Xoff Handshake

The following parameters are used to establish an Xon-Xoff handshake.

Xoff Threshold Level

The Xoff threshold level is the number of empty bytes remaining in the buffer when the plotter sends the Xoff trigger character to the computer, telling it to stop sending data. On most systems and with most plotters, 10 is a suitable value. The Xoff threshold level is specified by the first parameter in an ESC . I command.

Xon Trigger Character

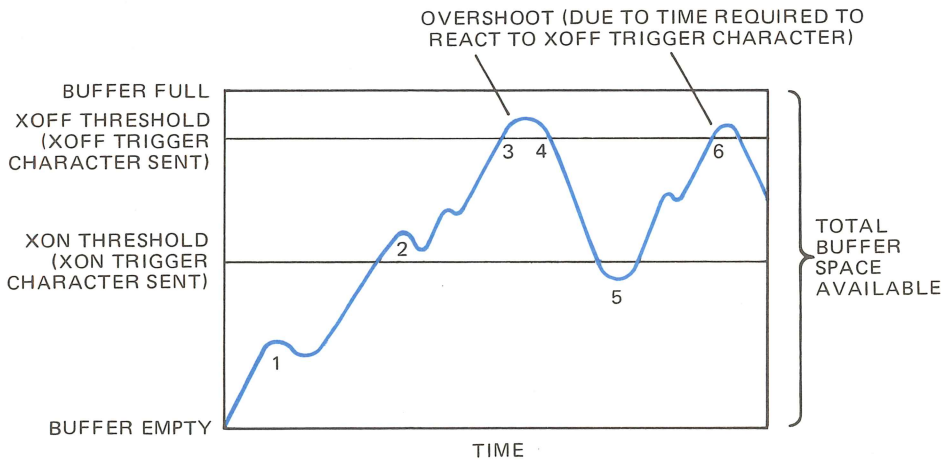
The Xon trigger character is the character the plotter will use to signal the computer that there is sufficient space in the buffer to resume sending data. By convention, the DC1 character (decimal equivalent 17) is the Xon trigger character. It is specified by the third parameter of the ESC . I command, the second parameter having been omitted by entering only a semicolon.

Xoff Trigger Character

The Xoff trigger character is sent by the plotter to signal the computer to temporarily stop sending data while the plotter processes what it has already received. By convention, the DC3 character (decimal equivalent 19) is the Xoff trigger character. It is specified by the second parameter of the ESC . N command.

A Diagram of Buffer Level

The following diagram is representative of the way the Xon-Xoff handshake works. The stages represented by the six numbers are described following the diagram.



Xon-Xoff Threshold Levels

1. Data enters the buffer faster than it can be acted on by the plotter, and the buffer starts to fill.
2. The plotter begins processing data faster than the computer sends it, and the buffer starts to empty.
3. The data again enters the buffer at a faster rate than the plotter can process it. The amount of data stored in the buffer reaches the Xoff threshold level, at which point the plotter sends the Xoff trigger character, stopping the flow of data from the computer.

4. Due to a finite delay between the time the plotter sends the Xoff trigger character and the time it takes the computer to react, a slight overshoot may occur.

5. Once the Xoff trigger character has been sent, when the amount of stored data drops to the Xon threshold level, the plotter sends the Xon trigger character to signal the computer to resume sending data. The Xon threshold level is automatically set at one-half the buffer size. If the Xoff threshold is greater than one-half the buffer size, the Xon threshold is reset to send the Xon character when one more byte than required by the Xoff threshold is available in the plotter's buffer.

6. Data is again stored in the buffer until all the data are transferred or until the Xoff threshold level is exceeded again.

Instructions Used to Establish the Xon-Xoff Handshake

Two commands are necessary to establish an Xon-Xoff handshake, the set handshake mode 2 instruction, ESC . I, and the set extended output and handshake mode instruction, ESC . N. The format of the set handshake mode 2 instruction is:

ESC . I

ESC[1] . I Xoff threshold level[2] ; omitted parameter ; Xon trigger character(s)[3] :

The format of the set extended output and handshake mode instruction, ESC . N is:

ESC . N

ESC . N intercharacter delay[2] ; Xoff trigger character(s)[3] :

An Example of an Xon-Xoff Handshake

The following commands will establish an Xon-Xoff handshake.

ESC . I25 ; ; 17 :

ESC . N ; 19 :

These commands will cause the Xoff character to be sent when there are less than 25 empty bytes in the plotter's buffer. Note that two semicolons follow this parameter. To implement the Xon-Xoff handshake, the second parameter must be omitted by including only the semicolon, or specifying it as 0. Except for a variation in the Xoff threshold level, the only likely variation in the two commands shown above might be the addition of a parameter specifying an intercharacter delay before the semicolon in the ESC . N command. The size of this delay would depend upon the system requirements and perhaps the baud rate. A system which supports an Xon-Xoff handshake may or may not require use of an ESC . M command to set plotter output protocol to match the computer system.

Enquire/Acknowledge Handshake

Handshakes Using ACK and ENQ

With the enquire/acknowledge handshake, the computer's operating system or the application program initiates the data exchange process by querying the plotter about the availability of buffer space. This handshake method derives its name from the two characters, ENQ and ACK, used on some Hewlett-Packard systems to verify that a peripheral is ready to receive output. This kind of handshake, when controlled by the operating system and using the characters ENQ and ACK (decimal equivalents of 5

[1]Text in reverse type represents a single ASCII character.

[2]An integer, base 10, without a decimal point.

[3]The integer decimal equivalent(s) of a string of from 1 to 10 ASCII characters, separated by semicolons.

and 6 respectively), might be called a "true" enquire/acknowledge handshake. It involves no additional steps in the application program to check for buffer space; it takes advantage of the fact that the operating system will check before sending a block of data to assure there is room for that block in the peripheral.

Plotter's Response to ACK

HP plotters will automatically send an ACK when they receive an ENQ unless ACK is the handshake enable character and some other character has been defined as the handshake response string. This "dummy handshake" (occurring when ACK is sent when some other character is the handshake enable character or some other handshake has been enabled) is not dependent on available buffer space and does not protect against buffer overflow.

An Enquire/Acknowledge Handshake in an Application Program

An enquire/acknowledge handshake can also be implemented in an application program, using characters other than ENQ and ACK for the handshake enable character and handshake response string. Never use as a handshake enable character any character that will be sent to the plotter as part of a plot command or a label because, once defined, the handshake enable character will be stripped from any incoming data stream before the data is sent to the plotter's parser or buffer. Also, you may want to use a digit as the handshake response string because it is the easiest variable to read into a program since it can be successfully interpreted as a string or numeric variable.

An enquire/acknowledge handshake implemented in an application program is more time consuming than one implemented in the operating system because, as an extra step in an application program, it requires an extra write and read each time data is to be sent. However, the handshake is far more efficient than the software checking handshake which uses ESC . B to ask how much empty space remains in the buffer. An enquire/acknowledge handshake in an application program can be implemented on any system, provided the communication protocol of the system has been taken into account.

Parameters Used in Enquire/Acknowledge Handshakes

The following parameters are used to establish an enquire/acknowledge handshake.

Handshake Enable Character

When initiating an enquire/acknowledge handshake, the computer sends a handshake enable character to ask the plotter if it has room for a block of data. The character ENQ (decimal equivalent 5) is frequently used as the handshake enable character. Printing characters or control characters which are used in plot programs, e.g., carriage return, line feed, shift-in and shift-out, should not be used as a handshake enable character.

Handshake Response String

The handshake response string specifies the character or characters that the plotter will send to the computer in response to a handshake enable character when the plotter's input buffer has room for another block of data. Use of characters which have special meaning to the computer should be avoided.

Immediate Response String

Certain systems require an immediate response from the plotter acknowledging the enquiry from the computer. Systems of this type include a computer that transmits data to the plotter after a certain time interval but before receiving a go-ahead signal from the plotter. If the plotter's buffer is full and the computer sends more data, the buffer will overflow. The immediate response string prevents this inadvertent transmission of data before the plotter is ready. The immediate response string is transmitted by the plotter immediately after the receipt of a handshake enable character and tells the computer, "Wait, I am checking my buffer space." NAK is sometimes

used for this character. It is specified by the second parameter in an ESC . N command.

Data Block Size

As with the hardwire handshake, this specifies the maximum size of any data block that the computer will transmit to the plotter. It is specified by the first parameter of an ESC . H or ESC . I command.

Other Parameters

The user may also wish to review the definitions given in the section, Matching Your Plotter's Communication Protocol. Which one of the two instructions, ESC . H or ESC . I is used to establish an enquire/acknowledge handshake depends on whether the computer system requires the use of any output trigger character, output terminator, echo terminator, or output initiator in the handshake process. The immediate response string, turnaround delay, and intercharacter delay, if any, will always be used no matter which instruction is used to establish the handshake.

Choosing the Proper Handshake Mode

To implement an effective enquire/acknowledge handshake, the user must know whether to use the ESC . H or ESC . I instruction. Only one instruction is correct for any system. That instruction determines whether the communication protocol set up for use with responses to plotter output commands is used with the handshake enable character and the handshake response string.

The ESC . H command establishes what is called handshake mode 1. This mode is used when the computer requires that all parameters set in the ESC . M instruction be used in the response to the handshake enable character.

The ESC . I command establishes what is called handshake mode 2. This mode is used when the computer expects only the turnaround delay and not the other parameters set by ESC . M to be included when the handshake enable character and handshake response strings are sent.

The following chart shows which parameters are used with handshake mode 1, handshake mode 2, and in all responses to plotter output commands.

Parameter Usage in Plotter/Computer Communication

Parameter	With Handshake Characters		With Plotter Output Commands
	In Mode 1	In Mode 2	
Turnaround Delay	YES	YES	YES
Output Trigger Character	YES	NO	YES
Echo Terminator	YES	NO	YES
Output Terminator	YES	NO	YES
Output Initiator*	NO	NO	YES
Intercharacter Delay	YES	YES	YES

*7470 plotter only.

Instructions Used to Establish the Enquire/Acknowledge Handshake

The format of both the ESC . H and ESC . I instructions is identical and is given next:

ESC . H (or I) block size[1] ; handshake enable character[2] ; handshake response string[3] :

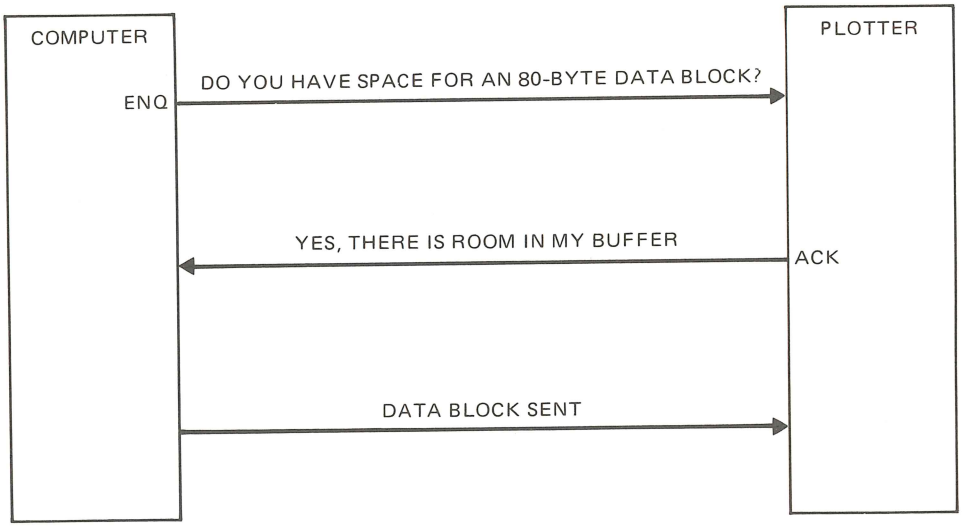
In the next section you will find examples of both handshake mode 1, which uses ESC . H, and handshake mode 2, which uses ESC . I.

Examples of Enquire/Acknowledge Handshakes

The simplest form of an enquire/acknowledge handshake would be established by sending the following command to the plotter:

ESC . I;5;6:

When this handshake is implemented, block size defaults to 80 bytes because the parameter is omitted by entering only the semicolon. The handshake enable character is ENQ, which is specified by its decimal equivalent 5, and the handshake response string is ACK, which is specified by its decimal equivalent 6. The following diagram illustrates data exchange as it will occur when this handshake is implemented.



Enquire/Acknowledge Handshake — Example 1

In many systems, additional communication protocol will have been specified using the ESC . M and/or ESC . N commands. When this is true, it is imperative that the proper set handshake mode instruction, ESC . H or ESC . I, be used to establish an enquire/acknowledge handshake. Let's assume a system required the following:

no turnaround delay,
output trigger character, DC1 (decimal equivalent 17),
echo-terminate character, line feed (decimal equivalent 10),
output terminator, carriage return (decimal equivalent 13),
data block size, 80 bytes,
handshake enable character, ENQ (decimal equivalent 5), and
handshake response string, ACK (decimal equivalent 6).

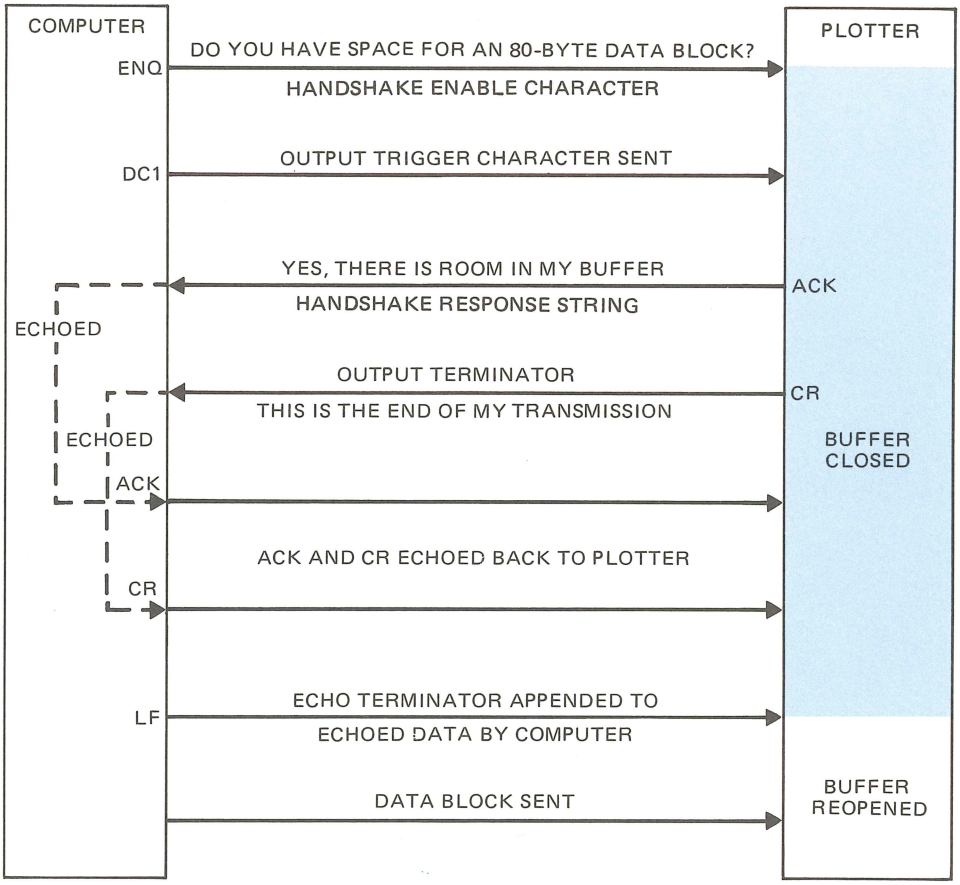
[1]An integer, base 10, without a decimal point.
[2]The integer decimal equivalent of an ASCII character.
[3]The integer decimal equivalent(s) of a string of from 1 to 10 ASCII characters, separated by semicolons.

If the ESC . I instruction were used, the handshake diagram would be identical to the previous diagram because the output trigger character, echo-terminate character, and output terminator would not be used with the handshake enable character and handshake response string.

If the ESC . H instruction were used, the data exchange which would result when the proper ESC . H and ESC . M commands, listed below, were sent to the plotter is shown next.

ESC . M;17;10;13:

ESC . I80;5;6:



Enquire/Acknowledge Handshake — Example 2

The next diagram shows the data exchange if there were no ESC . M command but there was an ESC . N command to set the following conditions:

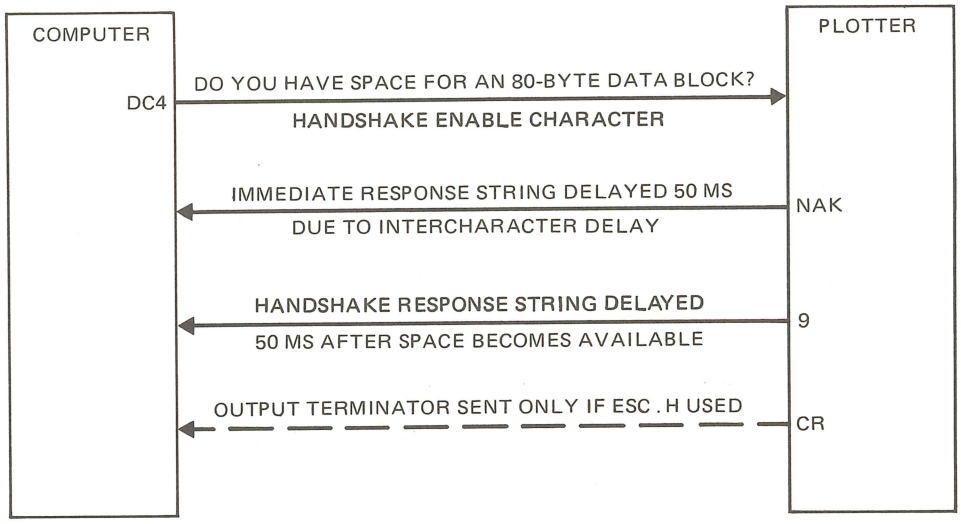
intercharacter delay, 50 milliseconds, and

immediate response string, NAK (decimal equivalent 21).

Similar diagrams would result for handshake mode 1, established by ESC . H, and handshake mode 2, established by ESC . I. The only difference is use of the output terminator when handshake mode 1 is established using ESC . H. In the commands, we have changed the handshake enable character and handshake response string to DC4 and "9" instead of ENQ and ACK to illustrate that characters other than ENQ

and ACK are often used for enquire/acknowledge handshakes in graphics programs. Some computers may not be able to read a nonprinting control character sent by the plotter; because a digit can be read into a character or numeric variable, a digit is often a good choice for a handshake response string.

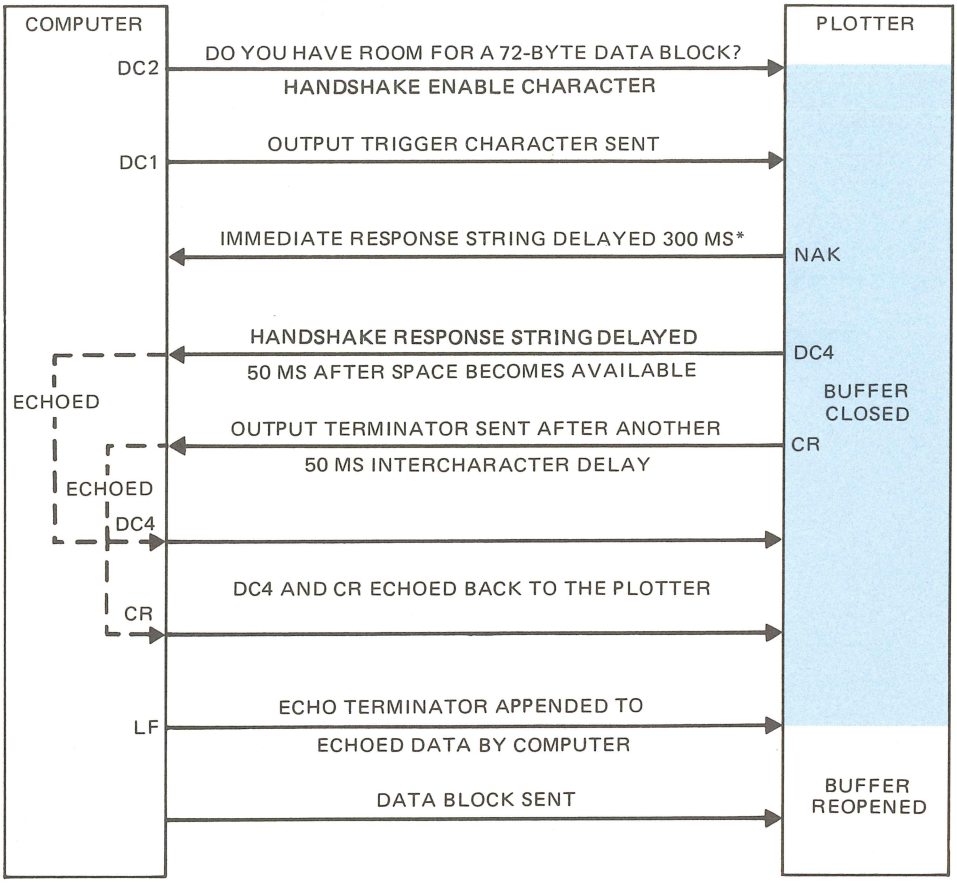
ESC . N 50 ; 21 :
ESC . H (or I) ; 20 ; 57 :



Enquire/Acknowledge Handshake — Example 3

The final example shows an enquire/acknowledge handshake when both the ESC . M and ESC . N commands are used with the ESC . H command. This would be necessary if the computer system required either an intercharacter delay or immediate response string and one of the parameters, turnaround delay, output trigger character, echo terminator, or an output terminator other than carriage return. Again we have used characters other than ENQ and ACK for the handshake enable character and handshake response string. The instructions and a diagram of the data exchange are shown next.

ESC . M 250 ; 17 ; 10 ; 13 :
ESC . N 50 ; 21 :
ESC . H 72 ; 18 ; 20 :



*300 MS DELAY IS TOTAL OF 250 MS TURNAROUND DELAY AND 50 MS INTERCHARACTER DELAY

Enquire/Acknowledge Handshake — Example 4

Software Checking Handshake

Two Methods

When your computer system does not implement one of the previously described handshakes in its hardware or operating system, you must add to your application program steps to assure that data is transferred from computer to plotter without loss. In the previous section, we have talked about one type of software handshake using the enquire/acknowledge principle. This is the preferred and more efficient of the two classes of software handshake.

The user should remember that long graphics programs utilizing the ESC . B command to implement software handshaking tend to degrade system performance. Where system performance is important, one of the other handshaking methods should be used whenever possible.

The second type of software handshake uses the plotter command, ESC . B, which causes output, namely the output of the number of empty bytes in the buffer. So, in order to establish this handshake, communication protocol must be specified to match the requirements of the computer system. You may want to review the section, Matching Your System's Communication Protocol. The following variables may be specified for the software handshake, using the appropriate command:

turnaround delay (ESC . M command)

output trigger character (ESC . M command),

echo-terminate character (ESC . M command),

output initiator (ESC . M command),

output terminator (ESC . M command), and

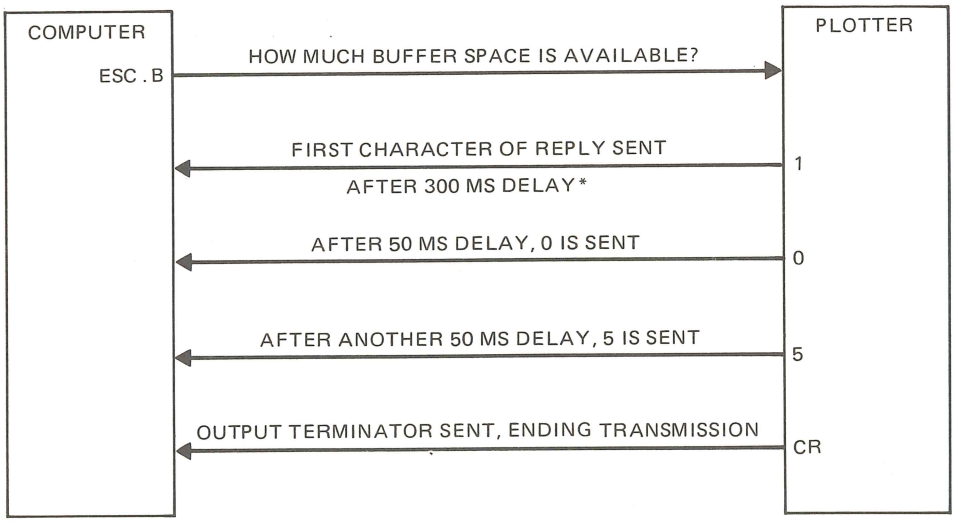
intercharacter delay (ESC . N command).

An Example Using ESC . B

The following diagram shows the data exchange between the computer and the plotter when an intercharacter delay and turnaround delay are specified, using the ESC . M and ESC . N instructions shown. All other parameters of these two commands assume their default values because they are omitted.

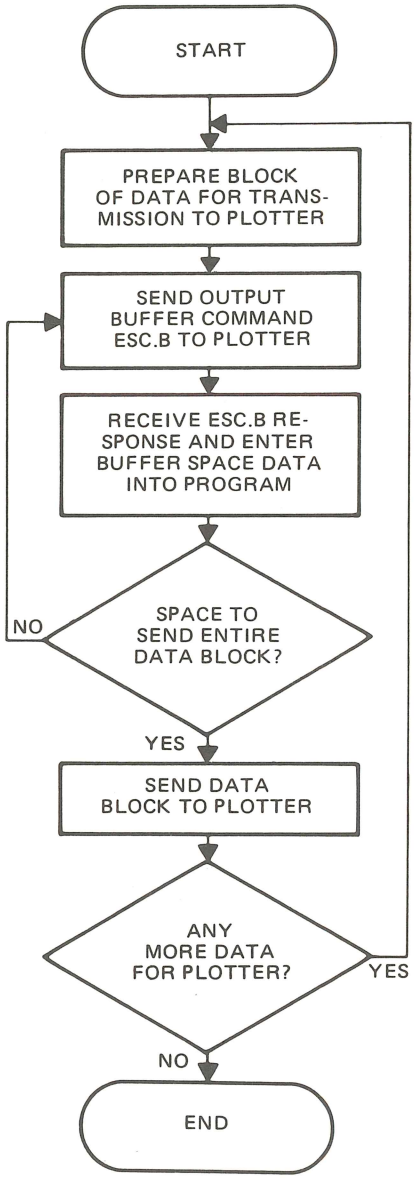
ESC . M 250 :

ESC . N 50 :



*300 MS DELAY IS TOTAL OF 250 MS TURNAROUND DELAY AND 50 MS INTERCHARACTER DELAY

In the second method, shown in the flowchart which follows, the user's program continually asks the plotter how many empty bytes remain in the buffer. The output buffer space command, ESC . B is used. When the plotter's response is bigger than the next block of data, the program transmits the data block to the plotter.



Either or both of the following techniques may be used to reduce the requests concerning buffer space available.

1. Count the number of bytes sent to the plotter and delay the initial request for available buffer space until enough data to fill the buffer once have been sent.
2. After a negative replay, wait a short time before again asking how much buffer space is available.

SUMMARY

All aspects of interfacing a plotter with a computer using the RS-232-C/V.24 interface have been discussed in this application note. The user's task is to determine and establish the best handshake for his particular system. The key to determining which type of handshake is best for a specific application is a thorough understanding of the plotter environment and communication requirements of the host computer.

The following questions concerning communication protocol need to be answered.

1. Does the computer send any character as a result of an input operation that would require definition of an output trigger character?
2. What turnaround delay or intercharacter delay, if any, is required?
3. Does the computer require some output terminator other than carriage return?
4. Does the computer supply an echo-terminate character (usually the case in full-duplex or echoplex systems)?
5. If an enquire/acknowledge handshake is to be used, does the computer require an immediate response string be sent in answer to a handshake enable character, so that data is not automatically sent after a certain time interval but before the handshake response string has been sent?

If the answer to any of the above questions is yes, specify the appropriate value as the corresponding parameter of the ESC . M and/or ESC . N command.

Once the computer's protocol is understood, these rules for data exchange can be transmitted to the plotter through the various device control commands.

One of the four handshakes — hardwire, Xon-Xoff, enquire/acknowledge, or software checking — can be established using other device control commands. The choice is limited by the plotter environment — hardwired or remote — and the capabilities of the computer. A given computer may or may not support Xon-Xoff protocol or a true ENQ/ACK handshake. Once a handshake has been established, all subsequent exchanges of plot data and plotter responses will conform to those communication formats and handshake.

When setting up a handshake, you should refer to your plotter manual as well as to this document. This document has focused on how to choose the best handshake for a system or application, and included methods for determining which parameters are required on a given system. Each computer manual has a detailed description of every device control instruction, including parameters and allowable parameter ranges. Using your manual along with this document should enable you to set up a handshake and successfully communicate with your plotter.

APPENDIX

*EIA RS-232-C and CCITT/V.24 Interface Lines for Hewlett-Packard Plotters with One Connector**

Wire/Signal Name	Circuit		Function		Signal Direction Relative to Plotter
	RS-232-C	CCITT/V.24	HP 7470	HP 7580	
Protective** Ground	AA/1	101	Used	Used	
Transmitted Data	BA/2	103	Data line from plotter to computer	Data line from plotter to computer	C ◄ P
Received Data	BB/3	104	Data line to plotter from computer	Data line to plotter from computer	C ► P
Request to Send	CA/4	105	Always high Internally strapped		C ◄ P
Signal Ground	AB/7	102	Used	Used	
Secondary Transmit Data	SBA/14	118	Data line from plotter to terminal	Not used	P ► T
Secondary Received Data	SBB/16	119	Data line to plotter from terminal	Not used	P ◄ T
External Clock Input	DD/17	115	Used	Not Used	C ◄ P
Data Terminal Ready	CD/20	108.2	Used	Used	C ◄ P

*HP Models 7580 and 7470 have a single connector which must go to the host computer ("modem"). An additional cable is available with the 7470 to enable connection of the plotter between a modem and terminal.
**Cannot be used for Signal Ground.

Wire/Signal Name	Circuit		Signal Direction Between Computer or Modem and Plotter
	RS-232-C	CCITT/V.24	
Transmitted Data	BA/2	103	C ◄ P
Received Data	BB/3	104	C ► P
Request to Send	CA/4	105	C ◄ P
Clear to Send	CB/5	106	C ► P
Data Set Ready	CC/6	107	C ► P
Signal Ground	AB/7	102	
Data Terminal Ready	CD/20	108.2	C ◄ P
			C ◄ T
Received Line	CF/8	109	

*HP Models 7220 and 7221 each have two connectors, one labeled MODEM and the other TERMINAL.

*Hewlett-Packard Plotters with Two Connectors Labeled Modem and Terminal**

Plotter		Signal Direction Between Terminal and Plotter
(Modem Connector)	**(Terminal Connector)**	
Data line from plotter to computer	Data line to plotter from terminal	P ◄ T
Date line to plotter from computer	Data line from plotter to terminal	P ► T
Clear to Send Plotter-activated; says "Prepare to receive data from the plotter"	Request to Send Terminal-activated; says "Prepare to receive data from the terminal"	P ◄ T
Modem-activated; says "Ready to receive data from the plotter"	Plotter-activated; tells terminal that plotter is ready to receive	P ► T
Modem-activated; says modem is operational	Plotter-activated; tells terminal that plotter is operational	P ► T
Used	Used	
In NORMAL mode: Plotter-activated; tells modem that plotter is operational In DTR BYPASS mode: wired through so signal supplied to terminal	No connection	
No connection	Always high (tied)	P ► T

Summary of Device Control Instructions Used to Establish Handshakes on Hewlett-Packard RS-232-C Plotters

ESC . @ maximum buffer size (ignored by 7470)[1] ; set configuration options (which include hardwire handshake)[2] :

ESC . B

Outputs the number of bytes currently available for data in the buffer. Response is a decimal number of four digits or less with no decimal point.

ESC . H block size or Xoff threshold level[1] ; handshake enable character[3] or omitted ; handshake response string or Xon trigger character(s)[4] :

ESC . I block size or Xoff threshold level[1] ; handshake enable character[3] or omitted ; handshake response string or Xon trigger character(s)[4] :

ESC . M turnaround delay[1] ; output trigger character[3] ; echo-terminate character[3] ; output terminator(s)[5] ; output initiator[3] (7470 only) :

ESC . N intercharacter delay[1] : immediate response string or Xoff trigger characters[4] :

[1]An integer, base 10, no decimal point.

[2]Decimal equivalent of a four-bit word, in ASCII.

[3]The integer decimal equivalent of an ASCII character.

[4]The integer decimal equivalent(s) of from 1 to 10 ASCII characters, separated by semicolons.

[5]The integer decimal equivalent of 1 or 2 ASCII characters, separated by a semicolon.

Computer Systems with Which Xon-Xoff Handshake Has Been Used with Hewlett-Packard RS-232-C Plotters

This list is intended to suggest that implementation may be possible on your system. Names or locations of installations using this handshake with a particular computer is not available from Hewlett-Packard.

Digital Equipment Corp. — all models

Hewlett-Packard 3000

Honeywell 6600

Prime Computer — all models

— NOTES —

HP-GL

7470
7220
7580
7585

Comp. Bind

7221

HEWLETT PACKARD

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