DATAGLOVE
MODEL 4

Operation Manual
Draft v.1

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VPL Research Inc.
3977 East Bayshore Road
Palo Alto, Ca. 94303
(415) 988-2550

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TABLE OF CONTENTS

SECTION 3 SET-UP (continued)

SECTION 4 HOST COMMUNICATIONS 4-1

SECTION 4 HOST COMMUNICATIONS (continued)

SECTION 4 HOST COMMUNICATIONS (continued)

SECTION 1

INTRODUCTION

The VPL Research DataGlove Model 4 allows you to translate hand gestures into control signals. The DataGlove measures and calibrates movements in the finger joints. These calibrated measurements may be passed on to a host computer for conditioning into any required format.

Essentially, the range of applications for the DataGlove is limited only by the hardware to which you connect it. The human hand itself is a very complex device, and its gestures cannot be accurately measured by any single sensor technology.

The DataGlove must be calibrated for each hand that wears it. VPL has reduced calibration to a simple, three-step procedure. Once calibrated, the DataGlove retains the calibration table to take the burden off the host computer.

The DataGlove can also recognize hand gestures, and pass this information to the host, eliminating yet another level of complexity from the application software. All of this makes the DataGlove Model 4 very quick and easy to incorporate into custom systems.

VPL Research supplies free test and calibration software for two of the more common host computers: the Apple Macintosh and IBM PC. Even if your application is to run on some other host computer, VPL recommends that you first establish communications with one of the VPL-supported hosts to gain familiarity with DataGlove communications.

It is impossible to anticipate each user's system configuration and application, so this manual provides information about the DataGlove which applies in all situations. Detailed instructions on VPL software for the DataGlove are supplied in the Test and Calibration Software Operation Manual.

SECTION 2

SYSTEM DESCRIPTION

The DataGlove system consists of these basic parts: the DataGlove itself, an optional Polhemus Position and Orientation Tracking system, and the DG4 Control Unit which conditions signals from the DataGlove's motions for transmission to the host computer.

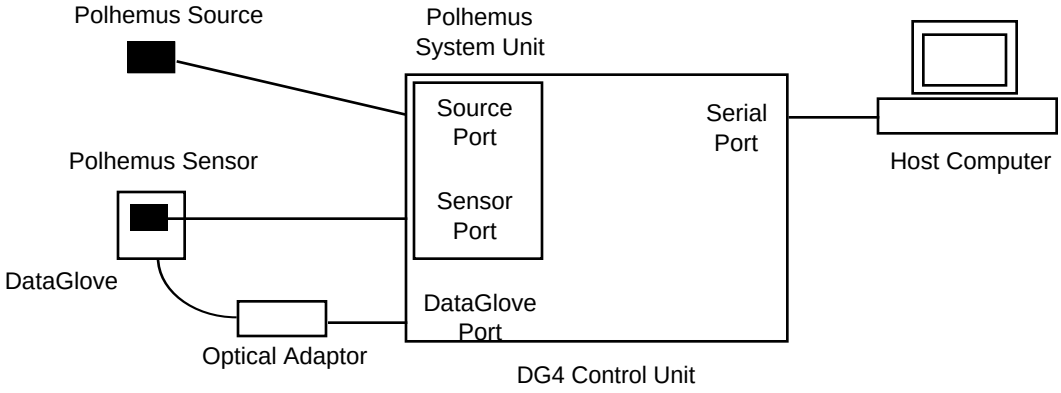

Figure 2-1: Block Diagram

THE DATAGLOVE

Flex Sensors

The DataGlove Model 4 senses the flexing of the finger joints. Flexing of the joints is measured by optical fiber- based sensors which, when bent, attenuate light passing through them. The ten optical fibers run across the DataGlove to the inner and outer joints of the thumb and fingers, and terminate at an optical adaptor containing the light sources for the fibers and the phototransistors which convert the flexion-controlled light levels into analog voltages. These voltages are fed to the Control Unit via a 25-pin connector.

The DataGlove Control Unit digitizes flex sensor values, which can be passed along to the host device, or interpreted by the Control Unit for calibration or gesture recognition. For details on reading Flex data from a host device, refer to Section 4, Host Communications.

Position and Orientation Sensor

The DataGlove records sent to the Host in many applications need to be complemented by position and orientation sensor readings. The system supports the Polhemus devices Fastrak and IsotrakII, and are generally compatible with the DataGlove Model 2 and Model 2+ which incorporated the Polhemus Isotrak.

For reference, the position and orientation in space is defined by the position in space of a "magnetic sensor" in relation to its referential determined by its "magnetic source".

- " The magnetic source " emits calibrated and characteristic electromagnetic fields. In the most common configuration, the source is mounted in front of the user.
- "The magnetic sensor," which responds to the source's fields according to its relative position to it .

CONTROL UNIT

The main role of the Control Unit is to convert analog signals coming from the DataGlove into a suitable format for a host computer. The Control Unit does not simply perform analog/digital conversion; it also controls the timing and the light levels fed through the optical sensors. Thus, the Control Unit contains all necessary computation and storage means to coordinate data transfer between the DataGlove, the position tracking sensors, and the host computer.

The DataGlove Model 4 systems allows up to four gloves to operate simultaneously with one host computer.

There are virtually no controls on the Control Unit's front panel. Instead, the DataGlove system relies entirely on the host computer to initiate routines such as glove calibration and gesture recognition. Similarly, DataGlove records, which typically contain flex and Polhemus data, are requested by the host computer either one at a time, or at regular intervals. (DataGlove record formats are examined in detail in Section 4, Host Communications.)

The range of voltages generated by the DataGlove varies from hand to hand, and rather than rely on the host to calibrate the raw data coming from the optical sensors, the Control Unit contains enough memory to hold calibration tables, configuration information, and gesture recognition tables. Not only does this simplify communications with the host, but it also speeds up record transfers to and from the host.

RS232 serial ports are standard on the DataGlove Model 4 system, and alternative communication interfaces, such as VME and GPIB, are available as options. A set of DIP switches is provided on the back panel to set up the DataGlove's communication protocol.

HOST COMPUTER

Before the DataGlove can act as an input device in an application, it must be calibrated and told how to format its data for the application. The system configuration is set up by the host computer.

The host tells the DataGlove:

- When or how often to send records
- Which sensors to send and in what order
- Information about the hand wearing the glove.

To accomplish this, the DataGlove uses a simple language consisting of 27 (or so) user commands (described in detail in Section 4).

VPL-Supported Hosts

The DataGlove Model 4 system can be used with supported hosts like the Apple Macintosh series or the IBM-PC compatible models. In these cases, the system's power-up default configuration is probably the most useful because the user need not understand the complete command structure of the DataGlove 2 system in order to use it in an application.

VPL supplies free Test and Calibration software for the Macintosh or IBM PC according to your system requirements. Although your final application may run on some other host computer, VPL recommends testing the DataGlove with the software provided with the DataGlove Model 4 to gain familiarity with the DataGlove command structure.

A variation on the Calibration software, Gesture Editor, is available as an option from VPL. Gesture Editor records gestures as collections of sensor values within user-defined tolerances. When a gesture is repeated, the DataGlove recognizes it, and informs the host. Banks of gestures can be filed by the host or downloaded into the DataGlove as required.

The effect of the DataGlove depends entirely on the application software running on the host computer.

The DataGlove can grab other 3-D objects on the screen and manipulate them. Similarly, any of the DataGlove's sensors can be assigned to 3-D objects, so that complex structures can be "puppeted" in real-time.

If desired, you can use VPL's Test and Calibration software or the Gesture Editor to set up the DataGlove, and to then connect the DataGlove to another host computer for operation with custom software.

SECTION 3

SET-UP

This section covers initial set-up of the DataGlove Model 4 system with the VPL-supported host computers:

-the Macintosh

- IBM PC and compatibles

- Unix platforms

For information on connecting other host computers, please refer to Section 4, Host Communications.

PACKING LIST

The box containing the equipment should be carefully inspected upon arrival; if the box has been damaged during transportation, please notify VPL immediately, so that proper action can be taken.

The DataGlove Model 4 box contains:

- One DataGlove Model 4 Control Unit
- One DataGlove with fiber optic cable and optical interface box.
- One DataGlove extension cord (D25 female to D25 male).
- One RS232 communications cable (D25 female to D25 female) to connect the DataGlove 4 Control Unit to the host computer.
- One Macintosh-style communications cable adaptor (DIN8 male to D25 female) to connect to Macintosh host computer.
- One 3 conductor power cable which connects a 110 VAC wall outlet to the DataGlove Model 4 Control Unit.
- One disk with test and calibration programs for your host computer (IBM PC or Macintosh).

Check the packing list to ensure that these items are contained in the box and that they appear in proper condition.

CONNECTIONS

Caution: Before making any connections, make sure that power to the host computer, Polhemus system, and DataGlove Control Unit is switched off.

DataGlove to Control Unit Connection

1. Plug the DataGlove Optical Interface (the black box connected to the DataGlove optical fiber cable) into the upper D25 DataGlove socket on the Control Unit front panel.

2. If the application requires the user to be located further from the Control Unit, use the D25 male to D25 female extension cord in between the DataGlove box and the Control Unit.

Polhemus Connections

Caution: **The Polhemus System Unit must always be powered OFF whenever plugging or un–plugging source or sensor cables. Otherwise severe electrical damage may result to the Polhemus devices!**

Connect Polhemus Sensor:

1. *Attach the small, blue Polhemus sensor to the velcro patch on the back of the DataGlove*
2. *Plug the Sensor cord into the indicated D15 socket on Polhemus System Unit front panel.*

Position Polhemus source:

1. *Plug the connector located at the end of the source cord into the indicated Source port on the Polhemus System Unit's front panel.*
2. *Position the source close to the space where the DataGlove will be used.*

Caution: The Isotrak source generates a magnetic field. Do not put the source on top of a video-display as it will deflect the picture tube beams and temporarily distort the image displayed on the monitor. For similar reasons, keep the source away from magnetic media such as disks and tapes.

Caution: The performance of the Isotrak system can be influenced by magnetic fields other than those propagated by the source, so avoid placing metallic or magnetic objects close to the DataGlove. In particular, keep metallic objects out of the space between the source and the DataGlove.

Mounting the Polhemus Source

In the default configuration, the source should be mounted with the black surface down, and the pointed tip facing the user. In this configuration, the source position defines the back plane of a three-dimensional space . (See Figure below.)

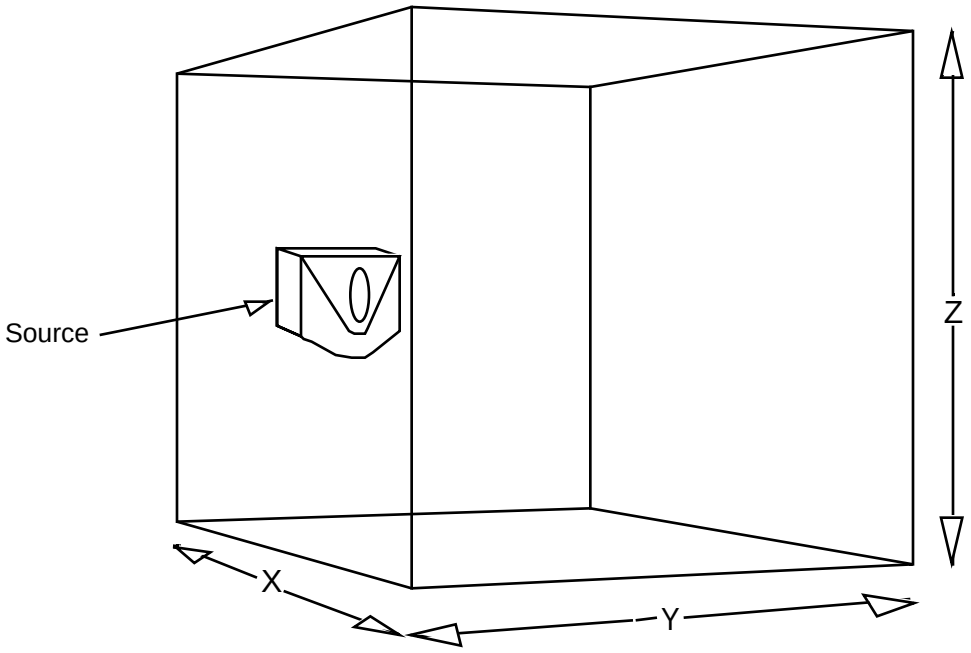

Figure 3-1: The DataGlove Coordinate Space

The DataGlove's X, Y, and Z coordinates are interpreted as follows:

X is always positive, and increases with the distance to the tip of the source to the DataGlove.

Y is negative on the left side of the source (as seen by the user facing the source), and positive on the right side on the source.

Z, the elevation of the DataGlove, is negative when the DataGlove is in a plane below the source, and positive when the DataGlove is in a plane above the source.

The default setting may be changed by commands such as Access Polhemus (described in Section 4).

SET-UP WITH MACINTOSH

This section deals with setting up the DataGlove for operation with an Apple Macintosh as the host. VPL Research supports the Apple Macintosh with these host applications:

- Test Software
- Calibration Software

These VPL applications run on all Macintosh models capable of running under System 6.x or System 7.x.

These applications typically communicate with a DG4 via the standard Macintosh MODEM port at 19200 baud with 8 data bits, no parity bit, and 2 stop bits.

Control Unit to Macintosh Connection

Connect Macintosh to Control Unit:

1. Plug the D25 cable to the RS232 port on the DG4 Control Unit's back panel.

2. Connect the supplied DIN8 adaptor to the other end of the D25 serial cable, then connect it to the Macintosh's MODEM port.

Communication Protocol for Macintosh

The DataGlove Communication protocol is controlled by a set of eight DIP switches on the Control Unit's back panel. To operate the DataGlove with a Macintosh as the Host device, set the Protocol switches for 19200 baud with 2 stop bits, as follows. (Refer to *Section 4 Host Communications* for further details.)

1. To select 19200 baud rate, turn switch 8 ON, and turn switches 7 and 6 OFF.

2. To select two stop bits, turn switch 5 off.

SET-UP WITH IBM PC

This section deals with setting up the DataGlove for operation with an IBM PC as the host. VPL Research supports the IBM PC with two host applications:

- Test Software
- Calibration Software

These VPL applications run on all IBM PC compatible models running under MS-DOS 3.x or later.

These applications typically communicate with a DG4 via the standard IBM COM1: serial port at 9600 baud with 8 data bits, no parity bit, and 2 stop bits.

Control Unit to IBM PC Connection

Connect PC to Control Unit:

1. Plug the D25 serial cable into the RS232 port on the DG4 Control Unit's back panel.

2. Plug the other end of the D25 serial cable into the PC's COM1: serial port.

Communication Protocol for IBM PC

The DataGlove Communication protocol is controlled by a set of eight DIP switches on the Control Unit's back panel. The recommended baud rate for communication with the IBM PC is 9600 baud, but other baud rates are also supported. (Refer to *Section 4 Host Communications* for further details.)

To operate the DataGlove with a IBM PC as the Host device, set the Protocol switches for 9600 baud with 2 stop bits, as follows:

1. To select 9600 baud rate transmission, turn switches 8 OFF and turn switches 7 and 6 ON.

2. To select two stop bits, turn switch 5 OFF.

POWERING THE DATAGLOVE

Connect the power cable:

1. Plug the female end of the power cable firmly into the back of the DataGlove Model 4 Control Unit.

2. Plug the male end into a grounded (3 conductor) 110 VAC wall outlet.

3. Turn on the DataGlove Model 4 Control Unit power switch located on the front panel of the unit.

   A red light within the switch confirms power is connected.

4. After 10 seconds (the time the Control Unit takes to initialize itself), switch on the Host.

Note: VPL recommends switching on the system units in the following order to avoid premature communications during initialization.

(1) Polhemus system unit

(2) DG4 Control Unit

(3) Host Computer

WEARING THE DATAGLOVE

Caution: The DataGlove Model 4 may be used in conjunction with a Polhemus sensor which contains low-voltage level currents. The sensor is, however, hermetically sealed. Although the flex sensors use optical fibers which do not carry any electrical current across the hand, the hand should, for safety, be dry before donning the DataGlove. Similarly, avoid handling liquids while wearing the glove.

Caution: Never pull on the optical sensors on the DataGlove. When putting on or taking off the DataGlove, pull on the fabric of the glove.

Putting On the DataGlove

Although the length of the DataGlove fingers may be longer than the user's fingers, the DataGlove will work properly if the following steps are taken.

1. Insert the hand into the DataGlove so that the optical fibers run across the back of the hand.

2. To ensure a snug fit, pull on the wrist part of the DataGlove until the base of the DataGlove fingers reaches the base of the user's fingers.

3. Make sure that the optical fibers are straight and that the longer ones run down the the middle of each finger.

4. To take off the DataGlove, grab the fingertips of the DataGlove, and pull.

Taking off the DataGlove

When taking off the DataGlove, avoid stressing or kinking the optical fibers. Store the DataGlove flat when not in use, and avoid rolling it into a bundle. Excessive wear and tear on the fibers shortens the life of the DataGlove.

Using Different DataGloves

DataGloves can be plugged in or unplugged while the DataGlove Model 4 Control Unit is switched on, without risk of damage.

The Control Unit Box should, however, be switched off, and back on again if a different Polhemus sensor is to be used, since the characteristics of each Polhemus sensor (contained in a ROM located in the D15 plug) are only accessed when the Control Unit is initialized. It is considered good practice to reset the Control Unit this way when changing DataGloves.

Note: The DataGlove Control Unit must be switched off to properly reset the Polhemus parameters. The Reset switch, the ColdReset command, and the WarmReset command do not have the same effect.

TROUBLESHOOTING

Symptom: Power light does not turn on.

Check power cord, power outlet and line fuse. If the problem persists, call VPL for technical support at (415) 988-2555, Palo Alto, California.

Symptom: Host not receiving data.

Confirm that the serial protocol is correct by checking the DIP switch positions on the back panel, and that the proper port is being used. (Refer to Connections section of this manual or the protocol legend on the Control Unit's back panel)

If the communications protocol is set correctly, check the host cable for incorrect or intermittent connections.

If connections are correct, the only remaining system elements that might cause the problem are the host computer's hardware and software. Check the Host serial port and protocol settings.

Symptom: Host receiving sensor "null" values.

If the values displayed for all the joints of the hands read "0," then the glove is not plugged in or is not powered.

Symptom: Host receiving incorrect sensor values.

The values might not be calibrated. Make sure that the calibration procedure has been followed. Refer to Test and Calibration Software Operation Manual for details.

MAINTENANCE

The DataGlove Model 4 system is almost maintenance-free. After prolonged use, the sensitivity of some of the DataGlove's optical sensors may vary slightly. Sensitivity adjustors are contained within the optical interface at the end of the DataGlove cable cluster. Contact VPL before attempting to make these adjustments by yourself.

SERVICING THE DATAGLOVE

VPL equipment being returned for repairs must have authorization. By requesting such procedure, we improve our service and turn-around time.

Before you call VPL for return authorization, gather the following information:

- The VPL model
- The Serial number for each part being sent back.
- A description of the problem.

When you supply this information to VPL, you will be given a Return Materials Authorization (RMA) number. This number must be visible on the outside of the package, on its packing list, and on the purchase order.

Please use the original shipping box or make sure that adequate packing material is used to prevent shipping damage.

SECTION 4

HOST COMMUNICATIONS

This section explains how to operate the DataGlove Model 4 with a host computer.

BASIC COMMUNICATIONS

The simplest way to establish a link between the DataGlove 4 system and the host computer is to use the Test program supplied with the DataGlove Model 4. Instructions for the Test program are supplied in the Test and Calibration Software Operation Manual.

If you wish to use the DataGlove Model 4 in your own application, make sure that your host application's communication protocol matches the DataGlove Model 4's protocol. Then, make all required connections.

When you turn on the DataGlove 4 system a system ID string (4 bytes) is sent to the host. To receive DataGlove records and system information, the host must send command strings to the DataGlove Model 4. Details of the available commands appear in the Command Summary.

SETTING THE PROTOCOL

The DataGlove Model 4 can operate with a variety of host computers. RS232 serial ports on the back panel are standard on the DataGlove Model 4. Eight DIP switches select the communications protocol as illustrated in the following figure:

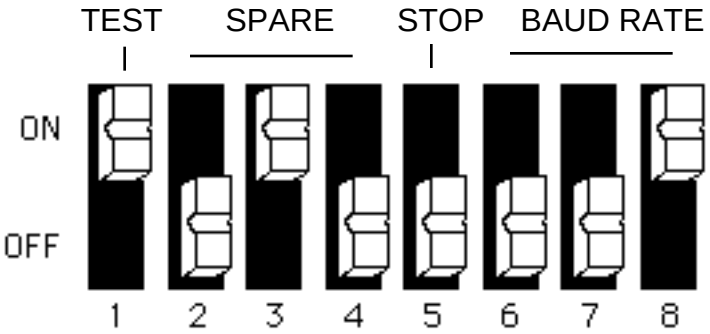

Figure 4-1: The Protocol Switches.

Baud Rate

The DataGlove Model 4's baud rate is set by Protocol switches 6,7,8, as shown in the following figure:

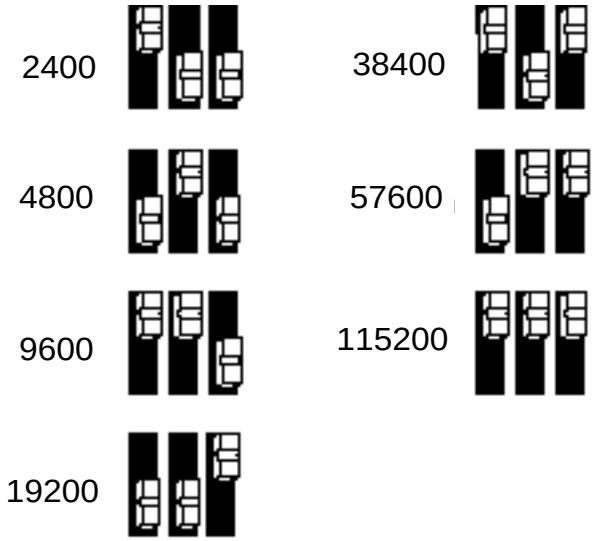

Figure 4-2: DataGlove Model 4 Baud Rate Settings

Stop Bits

Protocol switch 5 sets the number of stop bits, as shown in the following figure:

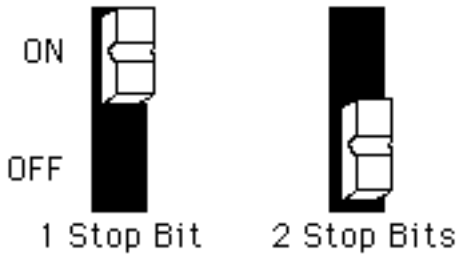

Figure 4-3: Stop Bits Switch Setting

Diagnostic Mode

Diagnostic mode switch 1 selects the Run or Test mode, as shown in the following figure. Normally the DG4 is operated solely in a Run mode, so DIP switch 8 will always be OFF.

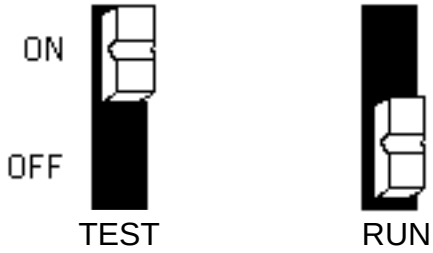

Figure 4-4: Diagnostic Switch Setting

RS232 Communication with the Host

The DataGlove Model 4 is shipped from the factory ready for RS232 communication protocol with the host. The following figure shows how the protocol switches (on the Control Unit's back panel) should be set:

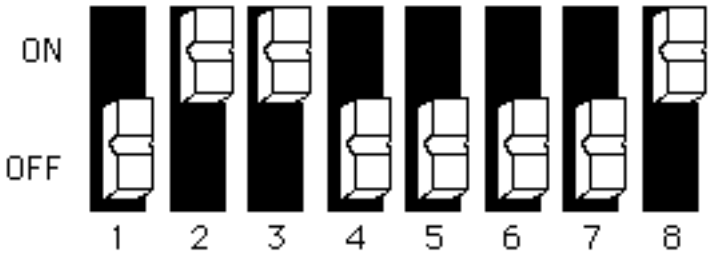

Figure 4-5: Factory Protocol Settings

The factory protocol settings are:

- 19.2 k baud
- 2 stop bits

If you wish to change the protocol settings, adjust the Protocol switches as directed in the corresponding Protocol section.

CUSTOM HOSTS

Although the DataGlove Model 4 system can be used with hosts other than the Macintosh and IBM PC, VPL recommends using one of the supported hosts before writing custom applications. By testing the system with a VPL-supplied host, you can examine the test and calibration software and C source code supplied free with the DataGlove.

VPL recommends examining the following:

- Test and Calibration Software
- "C" Source Code for the Test Program

Test and Calibration Software

A simple way to test the DataGlove system is to operate the DataGlove Model 4 with one of the supported host computers running VPL's Test and Calibration software.

Once the system is calibrated, either by calibrating the glove or by downloading calibration tables from the host (see the Test and Calibration Software Operation Manual), disconnect the Control Unit from the supported host, and connect it to the other host.

The new host can now communicate with the calibrated DataGlove system. Before writing a DataGlove driver for your new application software, examine the C source code for the Test program. VPL supplies this code to help you understand how the supported hosts communicate with the DataGlove Model 4 system.

VPL C Source Code

The "C" driver source code is supplied on the Test program disk. You can port this code over to another host for inclusion in your own applications. VPL strongly recommends testing the system with existing software before attempting to port.

Serial Port Pin-out

For connecting the DataGlove Model 4 to host computers other than the IBM PC and Macintosh, please note that the Serial port uses only three RS232 lines: Ground, Send and Receive. Pin connections are as follows:

1. Connect D25 pin 7 to Signal Ground, GND.

2. Connect D25 pin 3 to Data Transmit, TxD.

3. Connect D25 pin 2 to Data Receive, RxD.

Note: You may have to swap D25 pins 2 and 3 if the host computer is set up as DTE (Data Terminal Equipment) instead of DCE (Data Computer Equipment). This is accomplished with a Null-Modem adaptor.

HOST COMMANDS

The key to all DataGlove applications is the transfer of data between the DataGlove Model 4 and the host computer. As the DataGlove Control Unit features no front panel controls, applications depend entirely on the host computer to initiate record transfers. The DataGlove Model 4 can be used in a mode reasonably compatible with the previous DataGlove models.

The host computer controls and accesses the DataGlove with a set of 27 commands. Host commands fall into three categories:

- Record Requests.
- System Commands.
- Queries

Record Requests.

Record requests tell the DataGlove Model 4 to transfer glove data records, and how often. Record requests also specify which sensor values to include in the records.

System Commands.

There are no knobs or switches on the Control Unit, so the DataGlove system relies on System Commands from the host to set parameters such as brightness levels in the optical sensors and the order of sensor values in records. A system command is used to download calibration tables into the DataGlove Control Unit.

System commands do not require responses from the DataGlove Control Unit, though the Cold Reset and Warm Reset commands prompt System ID data as if the Control Unit had been switched off.

Queries

Queries are requests for system information such as the version of firmware installed in the DataGlove Control Unit or the current LED brightness level.

Host Command Structure

DataGlove sensor readings are initiated by the host sending a command string over the serial line to the Model 4 Control Unit. All Host command strings are sent in the following order:

1. Leading Byte.

   The leading byte is always $24.

2. Command ID

   The command byte is in the range $41-$59 or $61-$79.

3. Data

   Command data specifies sensors and devices to include in DataGlove records, and DataGlove operating parameters such as brightness and cutoff levels. Some host commands require no additional data. The values of the flex sensor records can be output in 8 bit and 12 bit formats to maintain as much as possible software compatibility with the DataGlove previous software.

For details on specific commands, refer to Command Summary.

DATAGLOVE RESPONSES

DataGlove responses fall into the following three categories:

- DataGlove records

  DataGlove records contain instantaneous values of sensors requested by the host.

- Replies to queries

  Replies to queries provide current operating parameter values, such as the current firmware version and glove version.

- Error messages.

  There are four different categories of error messages related to the type of error encountered.

DataGlove Records

DataGlove records contain instantaneous values for any combination of the following two sensor types:

- Flex

  Flex sensors provide continuous values corresponding to finger joint flexing. Flex records can contain a maximum of 16 flex values. The default number of sensors is 10.

  The values are available according to the commands in either 8-bit or 12-bit format. The values given in 12-bit mode do not map directly onto the values given by a DataGlove Model 4.

- Polhemus

  Polhemus records contain six values which describe to the position (X, Y, and Z coordinates) and orientation (Yaw, Pitch and Roll) of the DataGlove.

The DataGlove Model 4 power-up default sensor record settings reflect likely situations. For example, the system initially assumes 10 sensors on the glove, even though up to 16 may be supported.

Details on each sensor data format appear later in this section.

Replies to System Commands and Queries

The DataGlove replies to queries in much the same way that it replies to record requests. First, it sends the same leading byte and command byte as it received, followed by the requested data. In general, queries are requests for current DataGlove Model 4 configuration information.

System commands generally require no immediate reply from the DataGlove, though they may affect the data included in subsequent records. Exceptions include ColdReset and the two WarmReset commands which the DataGlove Model 4 responds to with SystemID messages.

$FF Error Message

Error byte `$FF` back to the Host indicates that the bytes received did not fit the correct format or values. In this case any command string that may have been started is aborted. The Control Unit is reset, and then waits for a new complete command string.

$FE Error Message

Error byte `$FD` back to the Host indicates that the number of bytes received is less than or greater than the number of bytes expected. In this case any command string that may have been started is aborted. The Control Unit is reset, and then waits for a new complete command string.

$FD Error Message

`$FD error_code` is sent back to the hosat on certain type of errors. The data values for `error_code` is reserved for the manufacturer. In this case any command string that may have been started is aborted. The Control Unit is reset, and then waits for a new complete command string.

$FC Error Message

`($24 $FC host_command)` indicates that the Control Unit has received a command byte is a DG2 command which is no longer supported in the DataGlove Model 4 Control Unit. In this case any command string that may have been started is aborted. The Control Unit is reset, and then waits for a new complete command string.

DataGlove Response Format

DataGlove sensor readings are initiated by the host sending a command string over the serial line to the Model 4 Control Unit. All DataGlove record strings are sent in the following order:

1. Leading Byte.

   The leading byte is always $24.

2. Command ID

   The command byte is in the range $41-$59 or $61-$79.

3. Data

   In addition to sensor and parameter values, data strings often include a Device Enable byte or the number of bytes in the record.

For details on specific responses, refer to the Command Summary.

Command Byte

DataGlove responses are stamped with a header indicating which command was received.

For example, in response to a One-Shot record request, the DataGlove Model 4 responds with a One-Shot header, followed by one DataGlove record.

Similarly, the DataGlove Model 4 responds to a Repeat30 command with a Repeat30 header and a DataGlove record, thirty times per second.

Other command bytes are described in the Command Summary.

Device Enable Byte

DataGlove records contain readings for selected sensor devices only. A Device Enable byte specifies which devices are active. The Device Enable byte is included in both the host command and the DataGlove record.

There are two Device Enable formats. One is for the DG2-compatible 8-bit record commands Repeat30, Repeat60, and OneShot(8), and the other is for the fully featured DG4 12-bit record commands RepeatN, and OneShot(12).

The bitwise format of the DG2 Device Enable byte is "0000G0PF," where:

- F=Flex
- P=Polhemus
- G=Gesture

If any of the these bits are set, then the corresponding sensor readings are included in the record. For example, when the DG4 reads only Flex values, the Device Enable byte is "00000001" or $01; whereas if it contains both Polhemus data and Flex readings, the Device byte is "00000011" or $03.

The bitwise format of the DG4 Device Enable byte is "4321GRPF," where:

- F=Flex
- P=Polhemus
- R=Reserved
- 1,2,3,4=Selected Glove Ports 1, 2, 3, and/or 4

If any of the these bits are set, then the corresponding sensor readings for the selected glove are included in the record. For example, when the DG4 contains Flex readings for only Glove Port 1, the Device Enable byte is "00010001" or $11; whereas Flex readings for both Glove Ports 1 and 2 use the Device Enable byte "00110001" or $31.

Number of Bytes in Record

DataGlove records are not of a fixed size. They contain only as many readings for selected sensor devices.

The OneShot, Repeat60, Repeat30, and RepeatN commands (see Command Summary) are all requests for DataGlove records. The amount of data received is dependent on the type of sensor enabled in the Device Enable byte.

When enabled, the number of data bytes contained in each record is as follows:

Sensor Type	Number of Bytes in record
Polhemus	12
Flex (8-bit mode)	10 (default)
Flex (12-bit mode)	20 (default)

Polhemus records always contain the same number of values. By comparison, Flex records contain either 10 or 20 values depending on the 8-bit or 12-bit record modes used, (for the default number of sensors, 10).

Furthermore, Flex records will also vary if the user changes the active Number of Sensors. For instance, if the user wishes to monitor only the thumb and index finger joints, they may change the Number of Sensors = 4, and subsequently receive flex records containing only 4 (8-bit) values or 8 (12-bit) values.

In the case of DG4 record request commands, 12-bit OneShot and RepeatN, the number of Polhemus and Flex values per record are further multiplied by the number of glove channels selected.

Sensor Order

Flex records contain readings for 10-16 sensor values. On power-up, the DataGlove Model 4 defaults to 10 sensors, and transmits sensor values in the following order:

Byte#	Sensor
1	Thumb, inner
2	Thumb, outer (closest to finger tip)
3	Index, inner
4	Index, outer
5	Middle, inner
6	Middle, outer
7	Ring, inner
8	Ring, outer
9	Pinkie, inner
10	Pinkie, outer
11	Reserved
12	Reserved
13	Reserved
14	Reserved
15	Reserved
16	Reserved

To change the number of sensors, send a NumSensors command to the DataGlove Model 4. See the Command Summary for details.

To change the order of the sensors in the record, send a JointMap command. See the Command Summary for details.

Brightness Levels

The range of values read from the optical (or "flex") sensors depends to a large degree on the brightness of the light fed through the optical fibres. In the DataGlove Model 4, the brightness level can be adjusted by the user.

On power-up, the DataGlove uses default levels. Bright levels can be changed by the host with SetBright commands. (Refer to Command Summary.)

There are two SetBright commands. One is the DG2-compatible 8-bit SetBright command, where the LED brightness level is inversely proportional to the specified brightness value (per DG2 Control Unit hardware.) The other is the full 12-bit SetBright command, where the LED brightness level is directly proportional to the brightness value.

Repeat Rate/Baud Rate Trade-offs

The DataGlove Model 4 Control Unit is designed to communicate with typical host devices at 19.2 kBaud. This accommodates transfers of 32 bytes per 60th of a second. If you want the Control Unit to send records to the host every 60th of a second, avoid requesting records containing more than 32 bytes. Similarly, If you want the Control Unit to send records every 30th of a second, avoid requesting records containing more than 64 bytes.

For example, you can use Repeat60 to request 10-byte flex records and a 12-byte Polhemus records which, in addition to the 4-byte header, add up to 26 bytes (4+10+12=26).

You can, however, use Repeat30 with all data values enabled (4+1+20+12= 37 bytes) as this is well below the 64-byte limit. These numbers are based on a 19.2 kBaud rate; if you run at half the baud rate , you must plan on half the limit as well.

If the host requests more bytes than the DataGlove can handle, the Control Unit will only send out a new record when it has finished sending out the old one. Thus, if the host sends a Repeat60 request for all sensor values, the DataGlove will only send 30 records each second.

Polhemus Data Conversion

Polhemus orientation values (Yaw, Pitch and Roll) are reported in degrees. The positional coordinates, however, are scaled for convenience. To convert Polhemus values into real-world units, multiply the received values by the coefficients in the following table:

	Inches	Centimeters
Multiply by:	65/32767	164.64/32767
or by:	0.0019983	0.0050245

The above figures are valid for Polhemus X, Y, and Z values.

COMMAND SUMMARY

The host communicates with the DataGlove Control Unit with a set of 27 commands. The following pages describe these commands and the replies (if any) received from the DataGlove Control Unit.

Many of the DG4 commands are DG2 compatible, so DG2 users will have immediate access to the DG4 via previously developed DG2 software. A couple of these DG2-compatible commands (as noted) have no physical effect on the DG4, but are supported anyway for complete software compatibility. The rest of the former DG2 commands, which have not been carried over to the DG4 system, will respond with the specific Error byte $FC.

Command List

Record Requests	System Commands	Queries
Repeat60	Cold Reset	System ID
Repeat30 (8-bit)	WarmReset 1	QueryBright
RepeatN (12-bit)	WarmReset 2	QueryBright
OneShot (8-bit) *	SetBright (8-bit)	QueryCutoff
OneShot (12-bit)	SetBright (12-bit)	QueryOptions
	SetDim*	
	SetCutoff *	
	SetOptions	
	AccessPolhemus	
	Angles	
	NumSensors	
	FlexValues	
	GloveControl	
	JointMap	
	LoadTable	
	LoadCode *	
	LoadGestures	

***** Denotes DG2-compatible commands which have no effect on the DG4.

Notation and Datatypes

$XX = Hexadecimal number

XX = Decimal Number

All data used by the DataGlove Model 4 are binary numbers.

aa, bb, cc, dd, ee, ff, gg,hh,nn,ss,vv,xx, yy = Unsigned one byte integers.

data =A variable length set of unsigned one byte integers.

Default values

Glove version	= 25
Software version	= 40
Brightness Level per glove [0-3]	= $0CCD (= 3277 decimal)
Number of Sensors per glove [0-3]	=10
Flex Record Type per glove [0-3]	= 1 (1= Flex, 0= Angles)
Unrecognized Gesture	= $FF

The byte order for a variable set of unsigned one byte integers is sent with the most significant byte first (MSBLSB); thus `0CCD`is sent as `0C`, then `CD`.

Options Byte

The options byte defines the scale factor and the byte order of the data, as well as the assignment of the active port for DG2-compatible emulation.

Bit 7 = not used

Bit 6 = not used

Bit 5 = not used

Bit 4 = not used

Bit 3 = 8bit scale factor (1=DG2scale, 0=DG4 scale)

Bit 2 = DataGlove port high bit

Bit 1 = DataGlove port low bit

Bit 0 = byte order (1=MSBLSB, 0=LSBMSB)

The assignment of the DataGlove Ports for DG2-compatible commands via selecting bits 1 and 2 (above):

Glove 1 = Bit 2 = 0, Bit 1 = 0

Glove 2 = Bit 2 = 0, Bit 1 = 1

Glove 3 = Bit 2 = 1, Bit 1 = 0

Glove 4 = Bit 2 = 1, Bit 1 = 1

Repeat60

Requests DataGlove records at 60 records per second for specified devices.

Transmit		Receive		
$24	Leading byte	$24	Leading byte	
$41	Repeat60	$41	Repeat60	
vv	DG2 Device Enable Byte	vv	DG2 Device Enable Byte	
nn	number of bytes (Range: 0-36)	nn	number of bytes	
		data	Gesture byte + Polhemus values + Sensor values	

Repeat30

Requests DataGlove records at 30 records/second for specified devices.

Transmit		Receive		
$24	Leading byte	$24	Leading byte	
$42	Repeat 30	$42	Repeat 30	
vv	DG2 Device Enable Byte	vv	DG2 Device Enable Byte	
nn	number of bytes (Range: 0-36)	nn	number of bytes	
		data	Gesture byte + Polhemus values + Sensor values	

RepeatN

Requests DataGlove records at N records per second for specified devices. Data sampling rate N may be any user-specified value at 1-512 Hz.

Transmit		Receive		
$24	Leading byte	$24	Leading byte	
$61	RepeatN	$61	RepeatN	
ww	DG4 Device Enable Byte	ww	DG4 Device Enable Byte	
xx	frequency, 1st byte	xx	frequency, 1st byte	
yy	frequency, 2nd byte	yy	frequency, 2nd byte	
		nn	number of bytes(0-144)	
		data	Reserved byte + Polhemus	

values + Sensor values

OneShot - 8-bit mode (DG2 style)

Requests one record for specified devices.

Transmit		Receive		
$24	Leading byte	$24	Leading byte	
$43	OneShot	$43	OneShot	
vv	DG2 Device Enable Byte	vv	DG2 Device Enable Byte	
		nn	number of bytes	
			Range: 0-36	
		data	Gesture byte + Polhemus values + Sensor values	

OneShot - 12-bit mode

Requests one record for specified devices.

Transmit		Receive		
$24	Leading byte	$24	Leading byte	
$63	OneShot	$63	OneShot	
ww	DG4 Device Enable Byte	ww	DG4 Device Enable Byte	
		nn	number of bytes	
			Range: 0-144	
		data	Reserved byte + Polhemus values + Sensor values	

ColdReset

Resets Control Unit to power-up state. Clears all memory buffers, initializes variables, and returns system ID.

Transmit		Receive	
$24	Leading byte	$24	Leading Byte
$49	Cold reset	$49	Cold reset
		gg	Glove version
		ss	Software version
		nn	#sensor data sent

WarmReset 1 (DG2 mode)

Resets Control Unit for DG2-compatible operating mode. Clears command and output buffers, terminates all outputs, but leaves calibration tables and buffer memory allocation intact. System responds with system ID.

Transmit		Receive	
$24	Leading byte	$24	Leading Byte
$4A	Warm reset	$4A	Warm reset
		gg	Glove version
		ss	Software version
		nn	#sensor data sent

WarmReset 2 (DG4 mode)

Resets Control Unit for DG4 operating mode, with optimum sensor range-scaling. Clears command and output buffers, terminates all outputs, but leaves calibration tables and buffer memory allocation intact. System responds with system ID.

Transmit		Receive	
$24	Leading byte	$24	Leading Byte
$6A	Warm reset	$6A	Warm reset
		gg	Glove version
		ss	Software version
		nn	#sensor data sent

SetBright - 8-bit mode (DG2 style)

Sets bright level for manual brightness control.

Uses DG2-compatible 8-bit brightness level values, where the actual LED brightness is *inversely proportional* to the specified value.

Transmit Only

$24	Leading byte
$4D	SetBright
vv	level
	$00=brightest (decimal 0)
	$7F=dimmest (decimal 127)

SetBright - 12-bit mode

Sets bright level for manual brightness control.

Uses DG4 12-bit brightness level values, where the actual LED brightness is *directly proportional* to the specified value.

Transmit Only

$24	Leading byte
$6D	SetBright
xx	level, low-byte
yy	level, high-byte
	$0000=dimmest (decimal 0)
	$0FFF=brightest (decimal 4095)

Access Polhemus

Allows the user to modify the default settings of the Polhemus, by using Polhemus commands, as described in Appendix F of the Polhemus operating manual.

Transmit Only

$24	Leading Byte
$51	Access Polhemus
nn	number of bytes in Polhemus command Indicates how many of the 63 bytes are actually used in the command (=1 for supported commands).
vv	Polhemus command

At present, only the "K" and "m" commands are supported.

ASCII K (75 decimal or $4B) = Quiet mode on
ASCII m (109 decimal or $6D) = Quiet mode off

Caution: Do not send a command that will cause the Polhemus to send anything but the standard DataGlove Model 4 format. In particular, avoid sending ASCII F (70 decimal or $46) or ASCII C (67 decimal or $43).

Angles

Causes the system to output calibrated angles (when requested) based on calibration table downloaded from host.

Transmit Only
$24 Leading Byte
$54 Angles

FlexValues

Requests uncalibrated flex values 0-255 (0=bent, 255 = straight) in flex records.

Transmit Only
$24 Leading Byte
$57 FlexValues

NumSensors

Number of flex sensors to be sent in a flex record.

Transmit Only

$24	Leading Byte
$53	NumSensors
nn	number of sensors
	range: 1-16
	Default: 10

JointMap

Establishes the order of flex values in DataGlove records.

Transmit Only

$24	Leading Byte
$59	Joint Map
data	16 flex numbers.

Glove Control

Selects the number of sensors per glove. Ackowledges selected number of sensors.

Transmit Only

$24	Leading Byte
$73	Glove Control
aa	number of sensors for glove 1
bb	number of sensors for glove 2
cc	number of sensors for glove 3
dd	number of sensors for glove 4

LoadTable

Loads calibration table into Control Unit's memory. The table number is given by the joint number if dim, and by the joint number logically or'd with $80 if bright.

Transmit Only

$24	Leading Byte
$50	LoadTable
nn	table number Range 1-16 one table for each sensor
data	256 bytes of calibration data

LoadGestures

Loads a gesture file into Control Unit's memory. Effective for the currently selected glove.

Transmit Only

$24	Leading Byte
$5A	LoadTable
data	655 bytes of gesture data in calibrated angles format

SystemID

Requests current version of software, hardware, and glove.

Transmit		Receive	
$24	Leading byte	$24	Leading Byte
$44	SystemID	$44	SystemID
		gg	Glove version
		ss	Software version
		nn	#sensor data sent

QueryBright - 8-bit mode (DG2 style)

Requests current bright and dim values.

Transmit		Receive	
$24	Leading byte	$24	Leading Byte
$48	QueryBright	$48	QueryBright
		vv	Dim value range 0-255
		vv	Bright value range 0-255

QueryBright - 12-bit mode

Requests current bright and dim values.

Transmit		Receive	
$24	Leading byte	$24	Leading Byte
$68	QueryBright	$68	QueryBright
		xx	Bright value, low byte
		yy	Bright value, high byte range $0000-$0FFF

SetDim

(Sets DG2 dim level for manual brightness control.)

*DG2-compatible command has **no effect** on DG4.*

Transmit Only

$24	Leading Byte
$4E	Set Dim
vv	level
	$00=brightest
	$7F=dimmest

SetCutoff

(Sets the DG2 bright/dim calibration cutoff to the value passed.)

*DG2-compatible command has **no effect** on DG4.*

Transmit Only

$24	Leading Byte
$56	SetCutoff
vv	Cutoff value

QueryCutoff

(Sends the DG2 current bright/dim cutoff value to the host.)

*DG2-compatible command has **no effect** on DG4.*

Transmit

$24	Leading byte
$55	QueryCutoff

Receive

$24	Leading Byte
$55	QueryCutoff
vv	Cutoff value = $FF

APPENDIX A

TECHNICAL SPECIFICATIONS

PERFORMANCE SPECIFICATIONS

Joint Measurements

Hand Size:	The system provides the specified accuracy when the glove fits the user's hand reasonably well. For this reason, the DataGlove™ is available in three sizes.
Joint Coverage:	The system measures flexing and hyperextension of the metacarpophalangeal joints of the five fingers, the interphalangeal joint of the thumb and the proximal interphalangeal joints of the other four fingers.

Angular Coverage:	The system measures flexing and hyperextension of the joints over their full range.
Angular Resolution:	1 degree.
Static Accuracy:	Within 5 degrees over the entire range for the flexing and hyperextension.

Hand Position Measurements

Note: *Refer to corresponding Polhemus manual for latest specifications.*

Hand Position Coverage:	The system provides the specified accuracy when the DataGlove™ and the Polhemus sensor are located between 4 and 36 inches of the Polhemus source. Operation at a larger distance from the source (up to 10 feet) is possible with reduced accuracy.
Hand Orientation Coverage:	Orientation parameters (Yaw, Pitch and Roll) are transmitted. The orientation of the DataGlove™ is all-attitude.
Static Accuracy:	Position: 0.25 inch (Root-Mean-Square).
Angular:	1.5 degree (RMS).
Resolution:	0.8 degree.
Output Update Rate:	1-160 times per second, user definable.

ENVIRONMENTAL SPECIFICATIONS

Operating Environment:	Large metallic objects, such as desks and cabinets, located near the source or the hand may adversely affect the performance of the system. No strong magnetic or electromagnetic sources should be located near the system. (See Chapter 2 of the Polhemus manual.)
Temperature:	Operating Temperature,15ºC to 40ºC for the DataGlove™ at a relative humidity of 30% to 60%, noncondensing.

PHYSICAL CHARACTERISTICS

	Dimensions (inches)	Weight (ounces)
• DataGlove™	Handsize	5
• Source	2.4 x 1.4 x1.4	3.5
• Electronics Control Unit	19 x 15 x 7	320

POWER REQUIREMENTS

- 120 VAC or 240 VAC, switch-selectable, less than 50W