

5DT Data Glove 5 5DT Data Glove 5-W



Data gloves for the fifth dimension

User's Manual

5DT

<Fifth Dimension Technologies>

5DT Data Glove 5

5-sensor data glove

5DT Data Glove 5-W

Wireless 5-sensor data glove

Data gloves for the fifth dimension

User's Manual

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Unless otherwise indicated, the term "5DT Data Glove 5" in this manual refers to both the standard and the wireless data glove. The wireless glove will be indicated as "5DT Data Glove 5-W" in circumstances where there are differences between the two devices.

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1 Introduction

Thank you for choosing this product. We trust that you will have a lot of fun and satisfaction using it.

The 5DT Data Glove 5 measures finger flexure and the orientation (pitch and roll) of a user's hand. It can emulate a mouse on the hardware level, and the user can type while wearing the glove. These facts make it the ideal single input device for virtual reality applications.

Although every effort has been made to ensure that this is a rugged product, it must still be treated as a sensitive instrument. Do not leave it in the same room as your pet velociraptor or chihuahua.

Features

- Affordable quality
- One size fits many
- Extreme comfort
- 8-bit flexure resolution
- Platform independent - serial port interface (RS 232)
- Built in 2-axis tilt sensor
- Mouse emulation mode
- High update rate
- Bundled software
- Right and left handed versions available
- Wireless versions available (5DT Data Glove 5-W)
- Low crosstalk between fingers
- On-board processor and memory
- Quick "hot release" connection
- Cross-platform drivers

2 Setup and Installation

Please check to see that your 5DT Data Glove package contains all the necessary items. It will be difficult to properly install and use the product if any item is missing. To connect the glove to your computer, follow the instructions in the relevant section.

2.1 Package contents

The standard **5DT Data Glove 5** package consists of the following items:

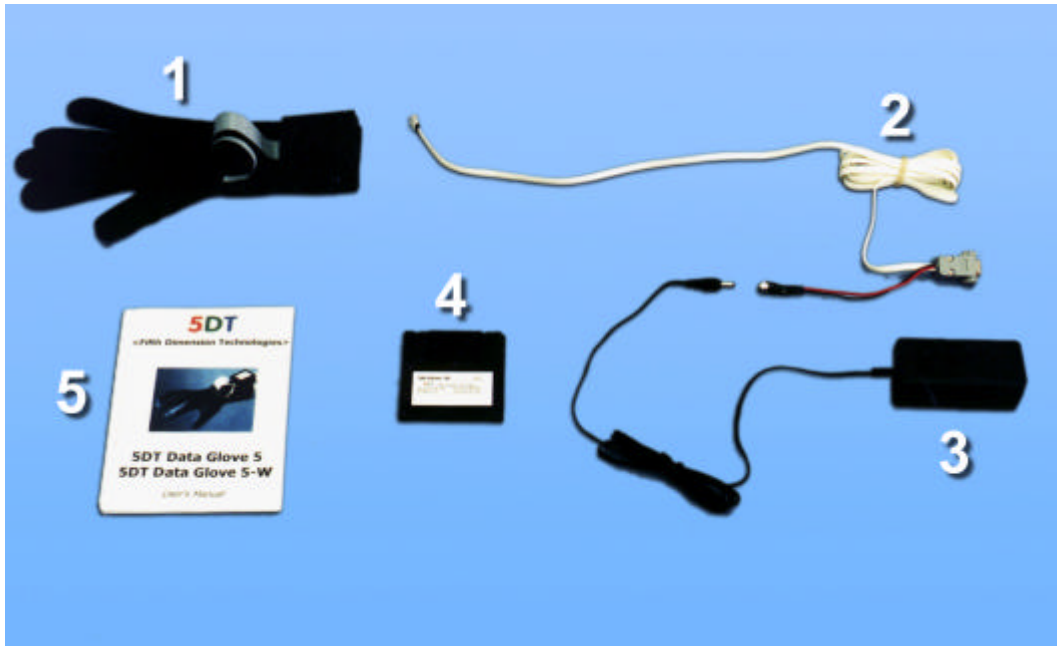


Figure 1 – Package contents for the 5DT Data Glove 5

1. The 5DT Data Glove 5 with fiber optic sensors, tilt sensor, ribbon cable and processing unit
2. The interface cable
3. A power supply unit
4. A set of installation disks and/or CD-ROM
5. This manual

The package for the wireless **5DT Data Glove 5-W** consists of the following items:

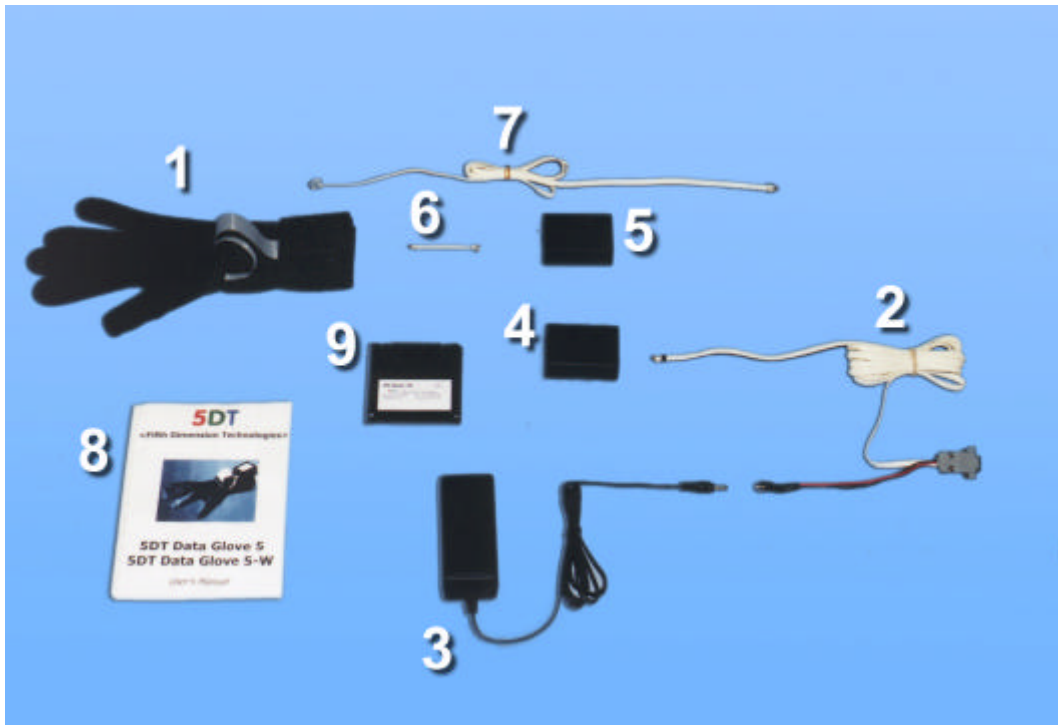


Figure 2 - Package contents for the 5DT Data Glove 5-W

1. The 5DT Data Glove 5-W with fiber optic sensors, tilt sensor, ribbon cable and processing unit
2. The interface cable
3. A power supply unit
4. Wireless receiver unit
5. Wireless transmitter unit
6. Short transmitter interface cable
7. Long transmitter interface cable
8. This manual
9. A set of installation disks and/or CD-ROM

Please note that batteries are **not** included in the package.

2.2 Connecting the standard glove

The 5DT Data Glove 5 consists of a **lycra glove** with embedded fiber optic sensors. These sensors are linked to the computer via an **opto-electronics** unit, a **ribbon cable** and an **interface box**. The ribbon cable also joins the interface box to the **tilt sensor**.

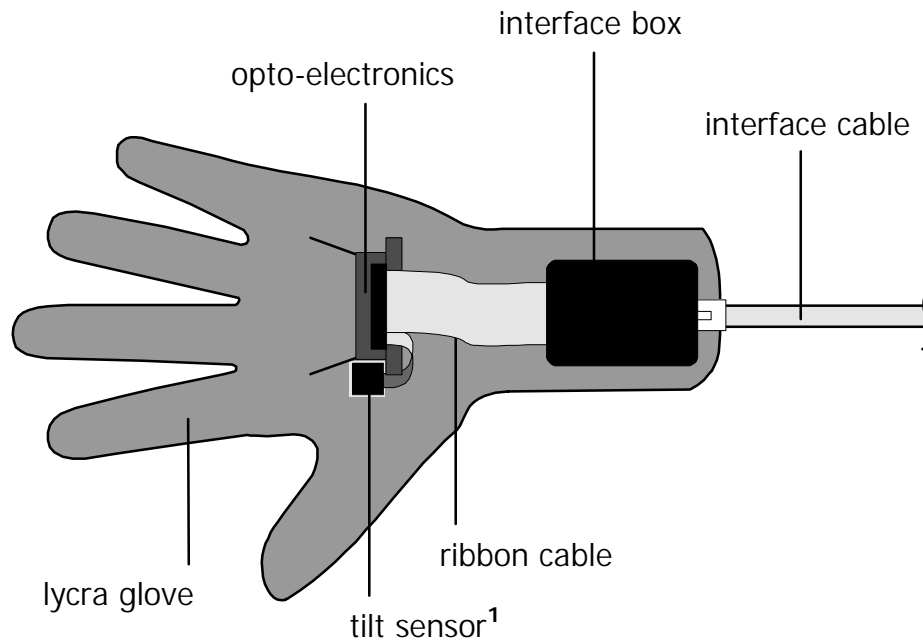


Figure 3 - The components of the 5DT Data Glove 5

The 5DT Data Glove 5 connects to a 9-pin RS 232 serial port (DB9 connector) via the interface cable. If the glove is to be used with a 25-pin serial port connector, a 9 to 25-pin adapter may be used.

The recommended procedure for connecting the standard glove to the computer is as follows (please refer to Fig. 4):

1. Connect the serial cable to the computer (DB9 connector).
2. Connect the power supply to the serial interface / power cable.
3. Connect the serial cable to the glove (RJ12 connector).

¹ The tilt sensor may be mounted to the glove (with velcro) in two orthogonal orientations, depending on whether the glove will be used mostly in a horizontal position or sideways (thumb pointing upwards) orientation.

The following diagram shows the glove connected to the computer:

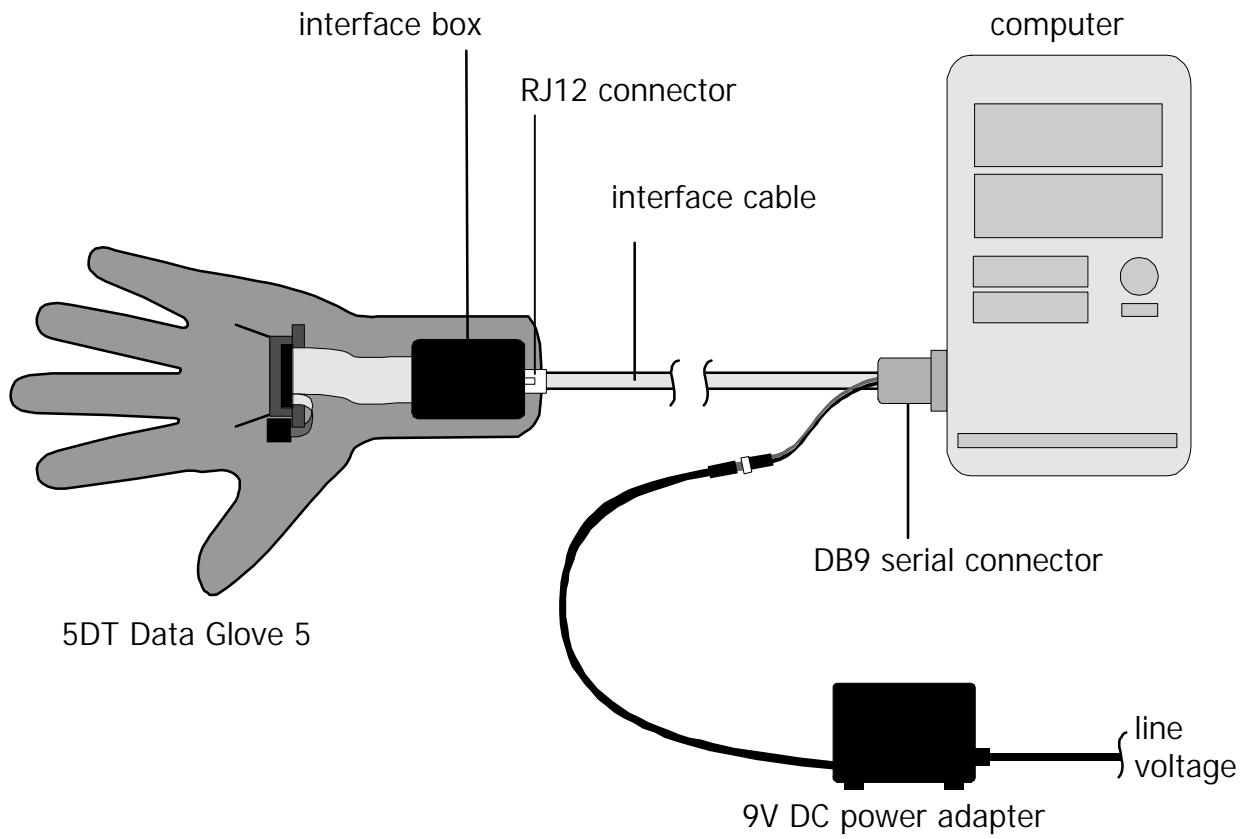


Figure 4 - The standard glove connected to the computer

2.3 Connecting the wireless glove

The wireless 5DT Data Glove 5-W is connected to the computer via a transmitter and a receiver unit. The recommended procedure for connecting a wireless glove to the computer is as follows (please refer to Fig. 5):

1. Connect the serial interface cable to the computer (DB9 connector).
2. Connect the power supply to the serial interface / power cable.
3. Connect the serial cable to the receiver unit (RJ12 connector).
4. Place a battery in the transmitter unit (PP3 9V).
5. Connect either the short or the long transmitter cable between the glove interface box and the transmitter unit.
6. Switch the transmitter unit on.²

² Always remember to switch the transmitter off after use!

The following diagram shows the wireless glove connected to the computer:

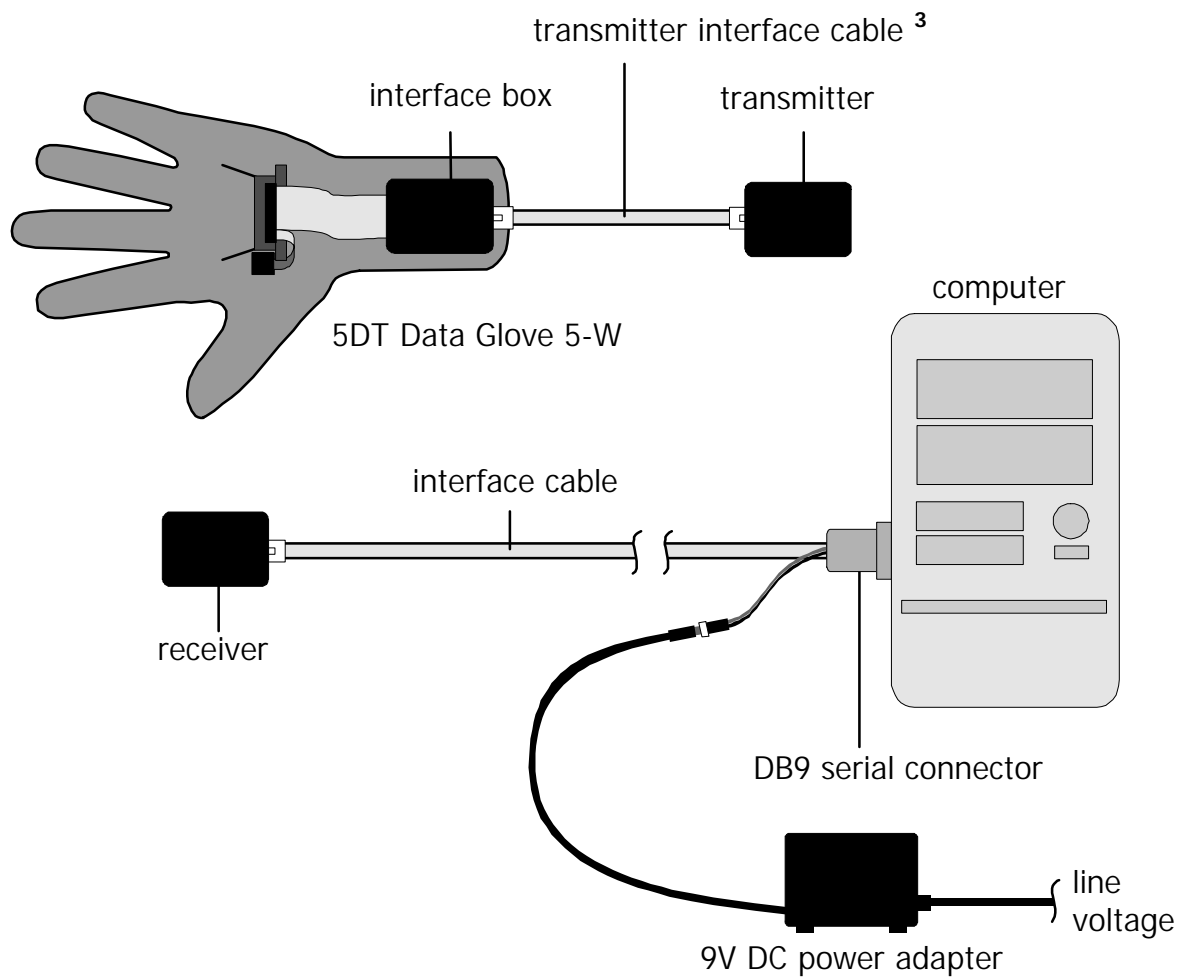


Figure 5 - The wireless glove connected to the computer

³ The transmitter interface cable comes in two lengths; a short and a longer cable. The short cable is intended for use when the transmitter unit is strapped to the wrist. The longer cable enables the user to put the transmitter unit in his/her pocket.

2.4 Software installation

The 5DT Data Glove 5 is supplied with a CD-ROM and/or a set of 3½ disks. These disks contain calibration and testing software, applications, drivers, demos, programming examples and this manual in electronic form.

Most of the supplied programs and software are intended for 32-bit Windows, and require Windows 95/98 or Windows NT.

To install the software onto your computer, insert the first disk (or CD) into your disk drive, run the program **setup.exe** and follow the on-screen instructions.

The suggested installation folder is,

c:\Program Files\5DT\Data Glove 5

The software may however be installed in any folder of your choice.

You will be prompted to insert the other disks as they are required. After installation, you may use the setup program to create shortcuts, in your Start menu and/or on your desktop, to the programs and documents that were installed.

Please take a careful look at the **Readme.txt** file in the main installation folder. This file explains the folders that were created during installation, and lists the latest information.

The software installed on your hard drive during installation includes:

- Glove Manager (more detail in section 3)
...**GloveMan**
- Glove Mouse (more detail in section 4.1)
...**Glove Mouse**
- Glove Driver (more detail in Appendix E)
...**Driver**
- Glove Demo (more detail in section 4.3)
...**Demo**
- Glove Programming Examples (more details in section 4.4)
...**Programming Examples\VC Sample**
- Glove Manual
...**Manual**

The default installation folder for shortcuts is:

...

The shortcuts that will be created in this folder are:

- Glove Manager
- Glove Mouse
- Demo
- Manual

The CD-ROM also contains the redistributable version of DirectX 7.0. You will need this if you want to run the DirectX implementations of the Glove Demos (DirectX and OpenGL demos are supplied). To install DirectX 7.0, open the

...\DirectX7.0

folder on your CD-ROM drive and run **DXSetup.exe**.

If you do not have the CD-ROM, you will need to download DirectX 7.0 from the Microsoft website (www.microsoft.com/directx/).

3 Glove Manager

The 5DT Glove Manager is a useful program that may be utilized for the following:

- *Connecting* the 5DT Data Glove to the computer
- *Testing* the 5DT Data Glove
- *Reprogramming* the on-board EEPROM
- Illustrating a *software calibration* routine for the data glove
- Illustrating a *gesture recognition* routine for the data glove
- Illustrating a *data logging* routine for the data glove

3.1 Running Glove Manager

Start the program by running **Glove Manager** from the start menu. The main program window will appear:

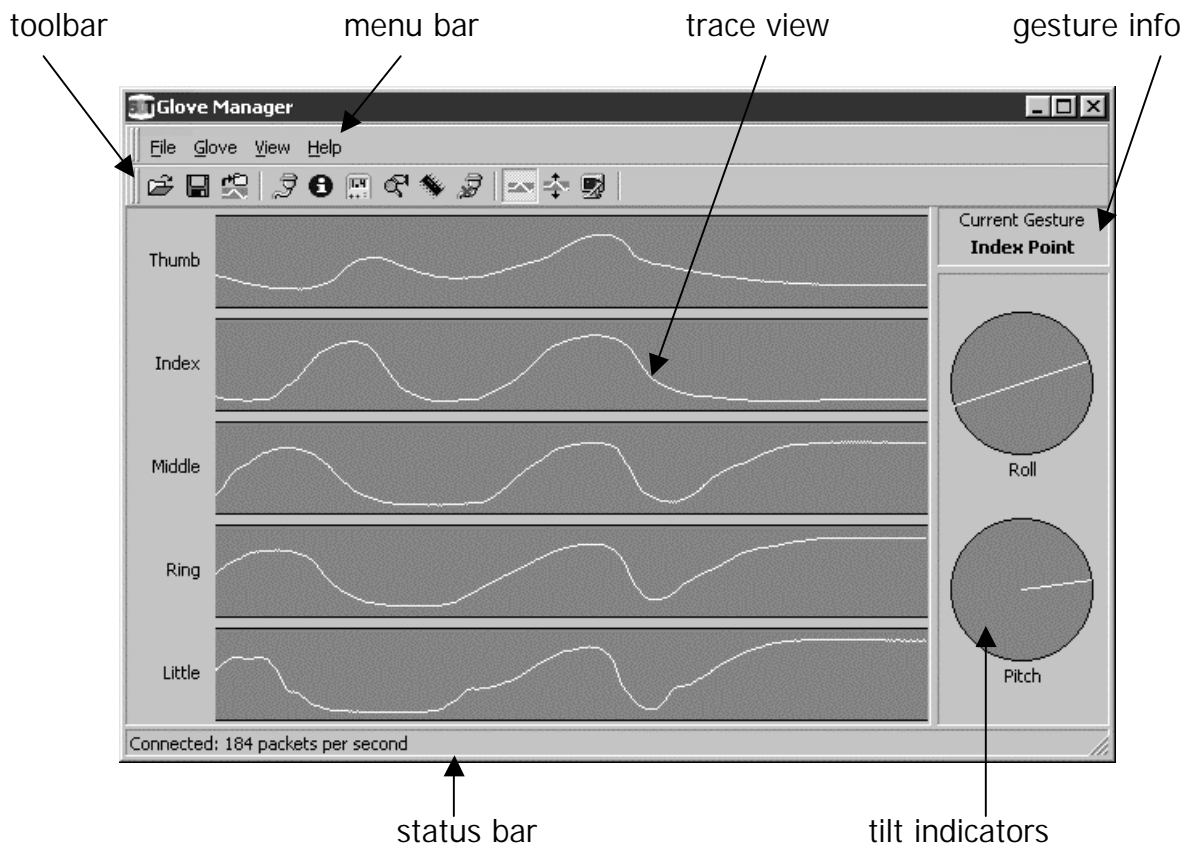


Figure 6 - The Glove Manager main window

The top of the window hosts a **menu** and a **toolbar**, and there is a **status bar** at the bottom. The middle part of the screen is divided into three sections. The biggest section is the **trace view**, which shows graphs of the flexure of each of the five fingers. The two circular **tilt indicators** are on the right, under the **gesture info**.

The menu and toolbar provide access to all the program's functions. The following table shows the menu structure, and indicates what each icon is used for:













Icon	Menu Command	Description	Shortcut
	File Open Calibration	Read the calibration information from an existing calibration file.	F3
	File Save Calibration	Save the current calibration information to a file.	F2
	File Save Data	Save the data received from the glove to a log file.	F4
	File Exit	Close the program.	Alt+F4
	Glove Connect	Establish communication with the glove via a COM port.	F5
	Glove Info	Show the information returned by the glove, e.g. Version	Ctrl+I
	Glove Calibrate	Calibrate the glove for a certain user's hand.	F8
	Glove Gestures	View/edit existing gestures and define new ones.	Ctrl+G
	Glove Program EEPROM	Reprogram the on-board memory of the glove.	Ctrl+E
	Glove Disconnect	Disconnect the glove.	F12
	View Raw Data	Shows raw data as it is received from the glove.	Ctrl+R
	View Scaled Data	Shows data that has been scaled with the calibration routine.	Ctrl+S
	View Options	View and set the program settings and display options.	F9
	Help About	Display program information.	

Table 1 - Glove Manager menu structure and icons

3.2 Connecting the glove to the computer

Before you can use the Data Glove, you need to connect to it. Choose **Connect** from the **Glove** menu, or click on the corresponding toolbar icon. The connect dialog box will appear, showing a list of available ports. Select the port (e.g. COM2) where the glove is connected and then click the **Connect** button.

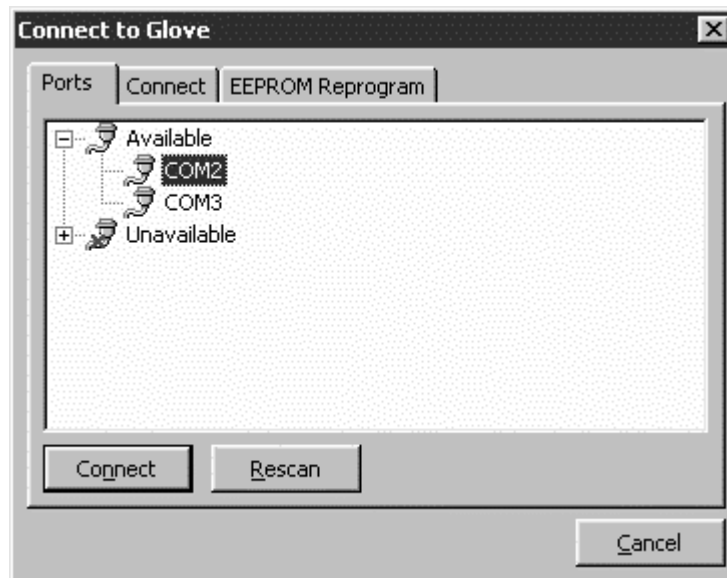


Figure 7 - Glove Manager's connect dialog box

The program will switch from the **Ports** tab to the **Connect** tab and then attempt to open the port and connect to the glove. The following message will be shown (or a slight variation):

```
Opening port COM2...
COM2 opened. Detecting Glove...
Glove found. Checking communication...
Communication established. Requesting info...
Info received. Requesting data stream...
Connected to Glove.
```

If a glove cannot be found, the exact reason for this will be displayed. See the troubleshooting section in Chapter 5 for help.

Click the **Close** button to shut the connect dialog box. In the main window, the graphs will show the current flexure of the fingers, as well as the tilting of the hand. As you flex and unflex your fingers, the traces on the flexure graphs will move higher and lower respectively. The tilt indicators will show the pitch and roll of your hand.

3.3 The software calibration routine

Each person has a different size hand. The 5DT Data Glove is designed to fit most users comfortably, but it needs to be calibrated in order to achieve the maximum sensitivity within an application.

*It is important to note that this software calibration routine **only** calibrates the glove for use within the Glove Manager program. It serves as an illustration/example only and it does not calibrate the glove for other programs/applications. You will have to develop a software calibration routine of your own for your applications. The process of doing so is described in Appendix F*

Please note that the supplied Glove Driver features a built-in software calibration routine (Appendix E).

To calibrate the glove for use within Glove Manager, select **Calibrate** from the **Glove** menu, or click the corresponding toolbar icon. The calibration dialog box will appear. The first calibration step is to set the **Range** of each of the sensors:

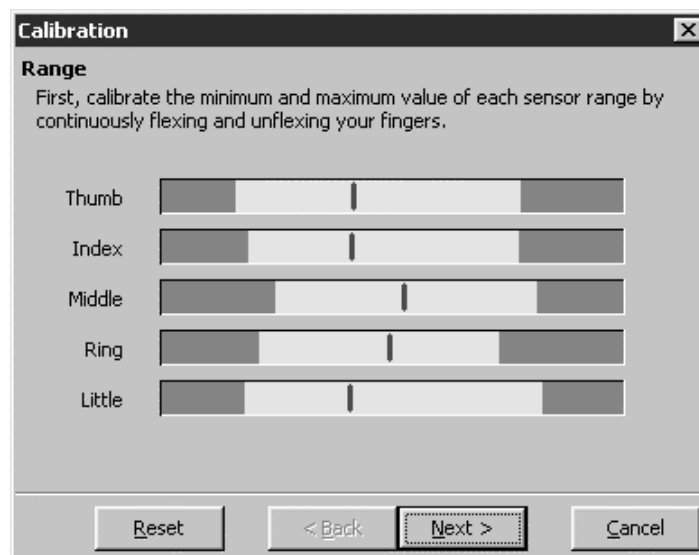


Figure 8 - Calibrating the glove: Range Setup

Repeatedly flex and unflex each of your fingers. It is important to keep your hand **relaxed** at all times, keeping the motion natural. **Do not force your hand into a gesture.** As you move your fingers, the minimum and maximum values of each of the sensors will be shown by the dark bars in the margins. The current value of each sensor is shown by the thick vertical red lines.

Once you are satisfied that the minimum and maximum values have been set, click the **Next** button to continue.

The second step is to set up the high and low thresholds for gesture recognition. This step is only necessary if you would like to optimize the use of the supplied gesture recognition routines. You can click the **Next** button to skip this step.

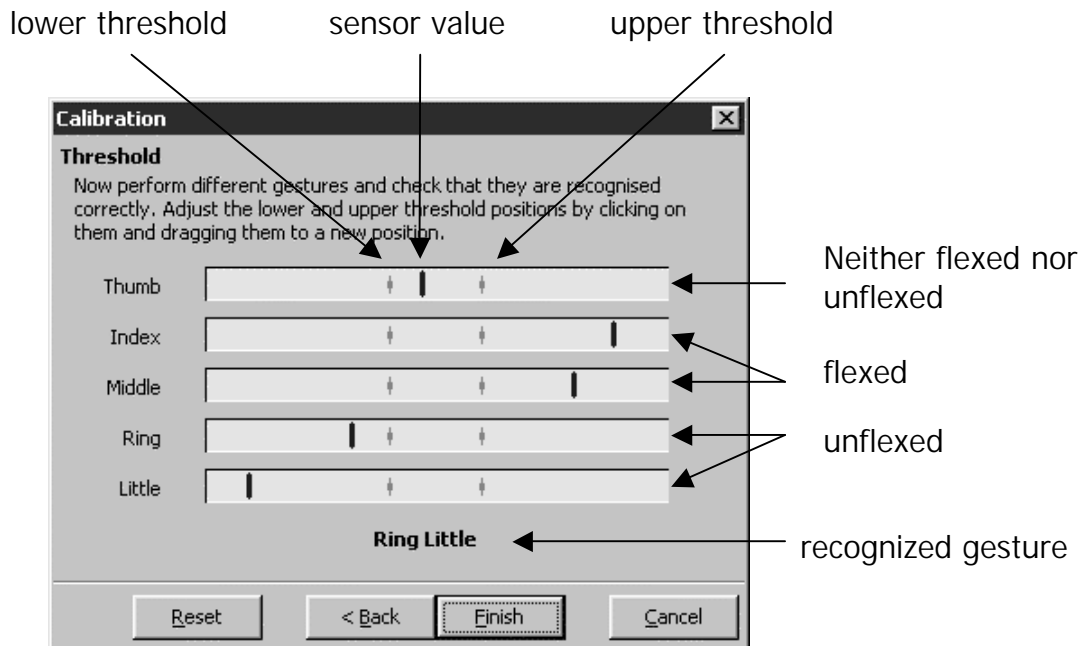


Figure 9 – Calibrating the glove: Threshold Setup

For each finger, there are two markings on the bar. When the sensor value (shown by the thick blue vertical line) is to the left of the first marking, this indicates an unflexed finger. When the sensor value is to the right of the second marking, a flexed finger is indicated. If the sensor value is between the two threshold markings, then the finger is neither flexed nor unflexed. In Fig. 9, the index and middle fingers are flexed, the ring and little fingers are unflexed and the thumb is neither flexed nor unflexed.

The default values should be adequate for most users, but you may wish to adjust the threshold values to achieve better gesture recognition results. To move the threshold positions, simply place the mouse cursor over the threshold marking, then click and drag it to the new position.

When you are satisfied that the calibration is complete, click the **Finish** button.

To save you time in the future, you may want to save the calibration information to a file. You can then load the calibration at any time very quickly. Select **Save Calibration** or **Load Calibration** from the **File** menu of the main window.

3.4 The gesture recognition routine

As mentioned in the previous section, the 5DT Glove Manager has the ability to recognize gestures performed by the user. The results of this gesture recognition are shown in the top right hand corner of the Glove Manager screen, under the toolbar. It is possible to define your own gestures. To do so, select **Gestures** from the **Glove** menu of the Glove Manager screen. The gestures dialog box will appear, showing the currently defined gestures.

*It is important to note that this gesture recognition routine **only** recognizes gestures within the Glove Manager program. It serves as an illustration/example only and does not recognize gestures for other programs/applications. You will have to develop your own gesture recognition routines for your applications.*

Please note that the supplied Win/NT Glove Driver features built-in gesture recognition routines (Appendix E).

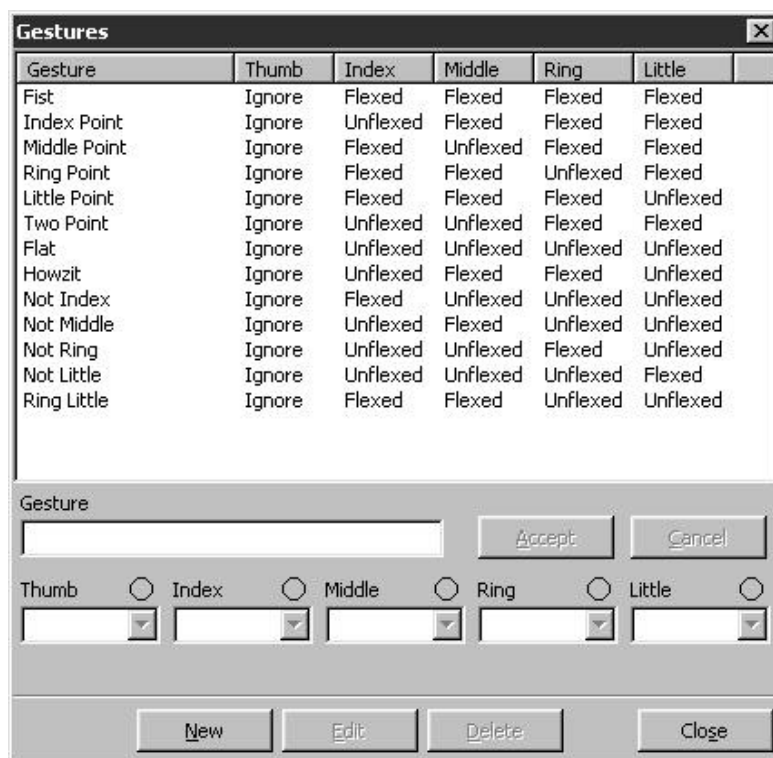


Figure 10 - Glove Manager's gesture dialog box

To create your own gesture, click the **New** button. Type a name for the gesture and then select either **Ignore**, **Flexed**, or **Unflexed** for each sensor. Once you are satisfied, click the **Accept** button.

You can edit the default gestures by selecting one of them and then clicking the **Edit** button. Once you have made your changes, click the **Accept** button. Click the **Cancel** button if you do not want to save your changes.

3.5 Saving the glove data to a log file

There are situations where you may want to "record" the data received from the glove by saving it to a log file.

Glove Manager can save the glove data in the following formats:

- CSV (Comma Separated Values)
- GDF (Glove Data Format)

The CSV format is very simple, and files in this format can be read into programs such as Microsoft Excel very easily. The GDF format is based on XML (Extensible Markup Language). This format is very versatile and is completely platform independent. XML is much more robust, and slightly easier to process than CSV, however it does take up more disk space. The specifications of the GDF file format can be found in Appendix D.

To save the glove data to a file, open Glove Manager and choose **Save Data** from the **File** menu. The following dialog box will appear:

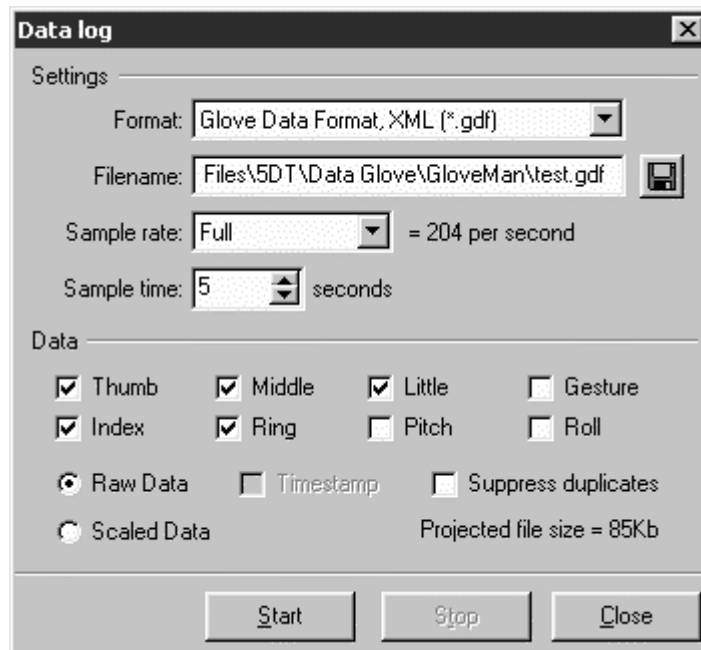


Figure 11 - Glove Manager's data log dialog box

It is possible to change the following settings:

- | | |
|--------------------|---|
| Format | Select either CSV or GDF format |
| Filename | Enter the name of the file you want to create. You can also click the disk icon to the right of the filename edit box. This will open a save dialog box. |
| Sample rate | Here you can select Full, Half or Quarter. Selecting Full will save each data packet received from the glove to the log file. The Half setting will only save every second packet, and the Quarter setting will save every fourth packet. |
| Sample time | Enter the maximum number of seconds you would like to record. You can always click the Stop button to stop recording before |

this maximum time has expired.

Raw data Select this option if you would like to save the data exactly as it is received from the glove.

Scaled data Select this option if you would like to save scaled (calibrated) data to the log file. This option is only available if the user has run the calibration procedure, or loaded a calibration file.

Select all the checkboxes for the data you wish to save. You may choose to save the flexure of any of the fingers, and even the tilt values (pitch and/or roll). Select the **Gesture** checkbox if you would like to save the gesture recognition results. These gesture recognition results are calculated from each data packet independently.

To start saving the data to the log file, click the **Start** button. Recording will stop automatically after the specified time interval, or when the **Stop** button has been clicked.

The last option is the **Suppress Duplicates** checkbox. If you select this option, then the program will only output a data value if it has changed. You will want to select this option if you have developed your own processing software and wish to take advantage of the saving in disk space, and quicker data processing times. The following two CSV output samples show the difference between the two settings:

Duplicate Suppression "off"	Duplicate Suppression "on"
5DT Data Glove Log File DataType=Raw Timestamp,Thumb,Index,Middle, Ring,Little 0,136,93,96,83,99 3,134,93,94,83,98 7,134,92,93,82,97 10,131,91,93,81,96 14,129,90,92,81,95 17,126,89,92,80,95 21,124,88,91,80,92 24,120,88,91,80,92 28,120,88,91,81,92 31,118,88,92,82,92 35,117,89,94,82,93 39,117,91,97,83,94	5DT Data Glove Log File DataType=Raw Timestamp,Thumb,Index,Middle, Ring,Little 0,136,93,96,83,99 3,134,,94,,98 7,,92,93,82,97 10,131,91,,81,96 14,129,90,92,,95 17,126,89,,80, 21,124,88,91,,92 24,120,,,, 28,,,,81, 31,118,,92,82, 35,117,89,94,,93 39,,91,97,83,94

Listing 1 - CSV File with suppression off and on

The program does not output a value if it is the same as the previous sample *of the corresponding finger*. Some programs will not be able to interpret the data if the duplicates have been suppressed.

3.6 Changing the program options

The Glove Manager has many options you can set to change how it works. To change them start Glove Manager, select **View**, then **Options**. The options dialog box will appear. These are some of the options you can adjust:

Load last used calibration file on startup

If this option is checked, then the last calibration file that was loaded will be reloaded each time the program starts.

Close connect dialog box on successful connection

Check this option to force the connect dialog box to be automatically closed when a successful connection is made with a glove.

Show blank gesture

When this option is checked, then a blank (invalid) gesture will still be shown. This implies that the gesture recognition mode is "Current Gesture". If this option is not checked, then the mode will be "Last Gesture" as the last recognized gesture will be shown, and blank (invalid) gestures will not.

Show toolbar hints

Check this option to enable the display of popup toolbar hints. These hints explain what each icon represents, and list the relevant shortcut key for that command.

You can change the appearance of the program by selecting one of the predefined **color schemes**. It is also possible to create your own scheme by adjusting the colors.

3.7 Reprogramming the on-board memory (EEPROM)

The non-volatile on-board memory in the 5DT Data Glove is EEPROM based. The glove will retain its settings in the absence of power.

Under rare circumstances, it is possible for this on-board memory to be lost or overwritten. This may occur if non-glove software writes spurious data to the port where the glove is connected, or if the glove interface experiences high levels of electrostatic discharge.

If the on-board memory is lost (or corrupted), it is very easy to re-program. Select **Program EEPROM** from the **Glove** menu. The EEPROM Reprogram tag will appear in the connect dialog box. Set the options to match the configuration of your glove (i.e. Left or Right handed glove, and whether there is a tilt sensor). Select the port to which the glove is connected and click the **Program** button.

If the glove is found to be working correctly (no problem with the EEPROM detected), you will be prompted to confirm the programming, otherwise the programming will start immediately.

Once the on-board EEPROM memory has been programmed, you will be requested to unplug the interface cable from the glove, and then reconnect it. This is to ensure that the glove can initialize itself to the new values.

4 Other Software

Please consult the **Readme.txt** file in the main installation folder. This file fully explains all the software that was installed on your hard drive.

4.1 Glove Mouse

...\Glove Mouse

The 5DT Glove Mouse program (**GloveMouse.exe**) is used to make the glove emulate a Microsoft mouse on the hardware level.

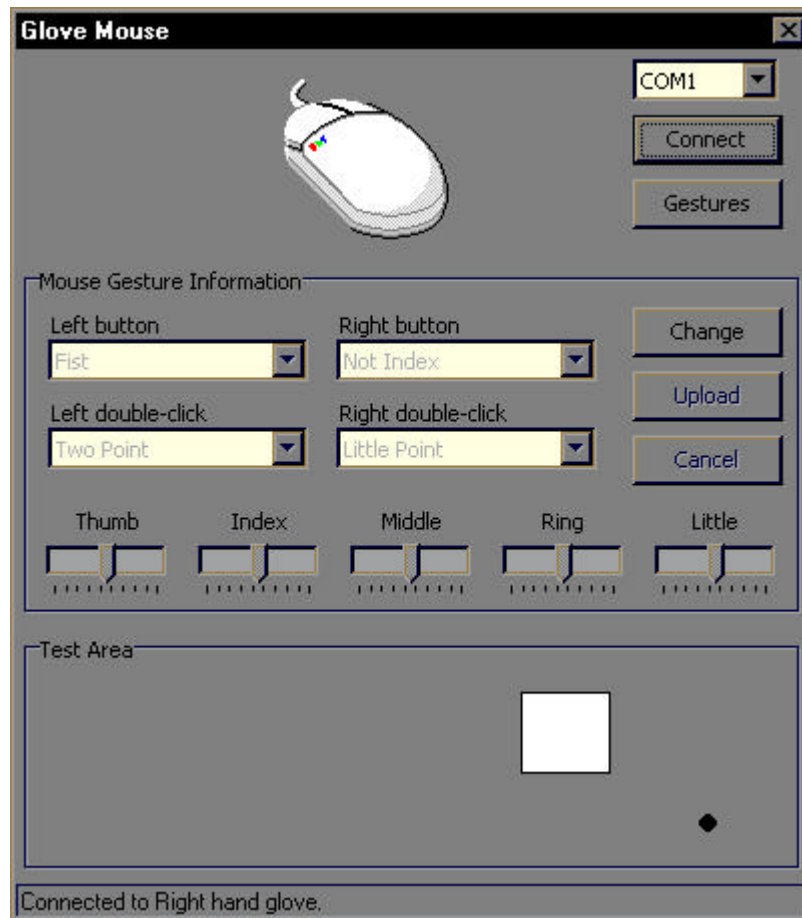


Figure 12 - Glove Mouse

Cursor movement is induced by tilting (rolling and/or pitching) the hand, and default gestures have been defined to emulate left and right button clicks as well as double clicks.

The default gestures are:

- | | |
|---------------------------|--|
| Left Click | - Fist |
| Left Double Click | - Index and middle finger point |
| Right Click | - Not index finger (middle, ring and little fingers pointed) |
| Right Double Click | - Little finger point |

Please refer to Fig. 18 in Appendix E for gesture illustrations. Glove Mouse currently only supports the right-handed glove.

To install the Glove Mouse

The Glove Mouse program must be run with the glove connected to a different COM port than the port where the mouse driver is active. For example, you could start with a mouse and mouse driver on COM1, and the Data Glove on COM2. Once the glove has been set to mouse emulation mode, shut down the computer and plug the glove into COM1. When the computer is restarted, the mouse driver will detect the glove as a mouse.

It is possible to modify the gestures used for left and right clicks, and left and right double-click by selecting another gesture from the gesture drop-down list. Once the new gestures have been selected, click on **Upload** to update the settings on the glove.

4.2 Glove Driver

... \Driver

The 5DT Data Glove Driver is explained in detail in Appendix E.

4.3 Glove Demos

... \Demo

These Demos currently allow you to do the following:

- View the animated hand on its own
- Use the animated hand to navigate a landscape
- Animate the movement of a character
- Animate the movement of a character in a landscape

The Demo screen is shown in Fig. 13

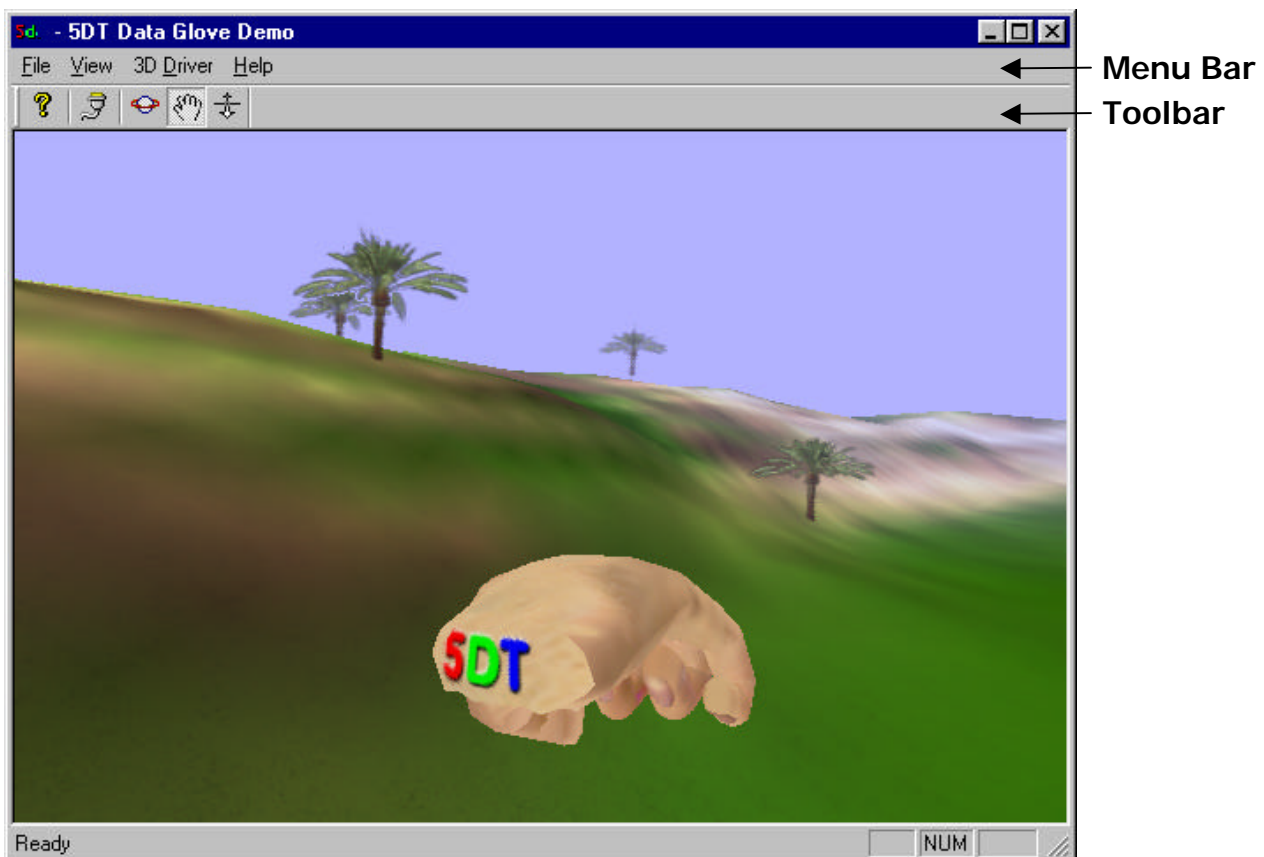


Figure 13 – Screen Shot of 5DT Data Glove 5 Demo

The following menu bar options are available:

File

Exit Allows you to exit from the program

View

Toolbar Display or hide the toolbar
Status bar Display or hide the status bar
Glove Settings Allows you to connect or disconnect the glove
Landscape Mode Switch the background landscape on or off
Object
 - 1. None No object loaded
 - 2. Hand Animated hand loaded
 - 3. Dude⁴ Animated character loaded

Please take note that the landscape and an object may be loaded simultaneously

3D Driver

Bilinear Filtering Switch bilinear filtering on or off
 Dual Texture Switch dual texturing on or off
Fogging Switch fogging on or off
Fill
 - Point Shown the landscape/object vertices only
 - Wireframe Show the landscape/object in wireframe mode
 - Solid Show the landscape in solid fill mode
Open GL Render the landscape/object with Open GL
 DirectX (ver 7.0) Render the landscape/object with DirectX 7.0
(DirectX 7.0 needs to be installed)
Setup... This option allows the user to change DirectX or OpenGL settings according to which of the two is currently selected.

Help

About About 5DT Data Glove Demo

The following toolbar options are available:



Displays the About Box



Opens the Connect Dialog Box



Allows the user to rotate the viewpoint around the loaded object by left-clicking and moving the mouse simultaneously



Allows the user to move the viewpoint around the loaded object by left-clicking and moving the mouse simultaneously



Allows the user to zoom in and out with respect to the loaded object by left-clicking and moving the mouse simultaneously

⁴ Dude is a relic from a bygone era. He will be fashionable every 20-30 years.

Using the Demo

When a particular object or character is chosen, a dialog box will appear with specific instructions on how to animate that specific object and/or move around in the landscape.

4.4 Glove Programming Examples

... \Programming Examples \VC Sample

Sample Source Code (Microsoft Visual C++ 6.0) is supplied to illustrate how the Glove Driver may be used.

*A Linux programming example is also available and can be found under the
 \LINUX\ directory of your CD/Disk*

5 Troubleshooting and Support

The following information is provided to help you diagnose any problems that may be encountered with your 5DT Data Glove 5 or 5-W. Please carefully consult this section before contacting your supplier.

5.1 General Troubleshooting

If the glove is not working at all, please work through the **physical connection problems** section of the troubleshooting procedure to identify the source of the problem.

Physical Connection Problems

1. Check that the glove is getting power. A red light (LED) will be shining if the power is adequate. Check that the power supply is 9V DC, center positive.
2. Check that the glove is connected to the right port. Try to connect the glove to another port (perhaps using a 9 to 25 pin adapter) and try again.
3. Check all the connections. Chapter 2 has information on how to correctly connect the interface cable to the glove, the power supply and the computer. Refer to Fig. 4 or Fig. 5.
4. Check the serial cable. Consult the interface cable specifications in Appendix B. You will find that a multimeter is helpful here.
5. Check that the port is working. Try connecting another device, for example an external modem.

If the 5DT Data Glove is recognized by your computer but not connecting properly, proceed directly to the **software connection problems** section.

Software Connection Problems

Run **Glove Manager** and select **Connect** from the **Glove** menu. If the **Ports** tab is selected, you will be able to see which COM ports are available. Remember that not all available ports will be physically connected to a socket on the back of your computer. Some ports may be unavailable because other programs have already taken control of the ports. Examples are mouse drivers and fax or communication programs.

Select an available port and click the **Connect** button to search for a glove on that port. If a glove is not detected, one of the following error messages may be returned by Glove Manager:

Could not open COMx

Glove Manager attempted to open the specified COM port, but was not successful. This is either because the port does not exist or because another program (or device driver) has already opened the port.

No response from Glove

The port could be opened and data could be sent, but no data (or invalid data) was returned by the glove.

No response from Glove: could be a modem

The port could be opened and data could be sent. The data that was returned indicates that a modem may be connected to the specified port.

Found a Glove but on-board memory has been lost

A glove was found, but it is responding in a way that indicates that the on-board memory is no longer valid. You should reprogram the on-board EEPROM memory and try to connect to the glove again. See section 3.7 for more information.

Communication failed

A glove could be detected, but was not responding correctly. This could indicate that the glove electronics are not functioning correctly. Try switching the glove off and try again. Reprogramming the on-board memory may solve the problem.

Could not read Glove information

Corrupted info header received

These messages indicate that a glove was found and it responded correctly, however the glove information could not be read (or was invalid). Switch the glove off and back on again, and then try again. If this does not help, try reprogramming the on-board EEPROM memory.

No data stream from Glove

A working glove was found, however it did not return a stream of data when requested to do so.

Foreign data stream. No glove found

When searching for a wireless glove, a stream of data was found, but it did not conform to the structure of the wireless glove protocol. This error is sometimes returned when trying to connect to a wireless glove that is outputting constant data. Try moving your fingers repeatedly while connecting to the glove to ensure the data is changing.

If your glove connects to the Glove Manager correctly, but there is a problem with the operation of the glove, proceed to the **performance problems** section.

Performance problems

This section deals with problems that may occur after Glove Manager is connected properly and reports no errors. Start Glove Manager and connect the glove as per usual.

*Please note that it is imperative that glove manager
is set to **raw data** mode in the **view** menu.*

Saturated High

If one of the data streams from a specific finger is saturated high, there could be one of two problems. Either one of the fibers has failed or the data glove has become uncalibrated. If, when flexing the relevant finger, the data stream remains saturated high, and does not change at all, it is likely that the fiber for that finger has broken. The glove will then have to be returned to the supplier (or 5DT) for repairs. If hardware calibration is necessary, please refer to Appendix G for detailed instructions.

Saturated Low

If one of the data streams is saturated low, it is more likely that the glove has become uncalibrated than a fiber having failed. If hardware calibration is necessary, please refer to Appendix G for detailed instructions.

5.2 Frequently Asked Questions (FAQ)

- Q** My glove is connected to COM2, but Glove Manager reports that this port is not available.
- A** There may be a mouse driver, or other program that has already opened that port. Once a program or driver has opened a COM port, no other program will be able to access that port until the first one closes.
- Q** The Glove Manager program reports that the on-board memory of my glove has been lost.
- A** Choose **Reprogram EEPROM** from the **Glove** menu. See section 3.7 for more details.
- Q** Is it possible to use the glove in a LINUX environment?
- A** Yes. The 5DT Data Glove Driver is a cross-platform driver and includes a LINUX driver.
- Q** Is it possible to use the glove in a UNIX environment?
- A** Yes. UNIX drivers are available. Please contact 5DT for more information.
- Q** How do I clean my glove?
- A** With a great deal of finesse. The lycra part of the glove may be soaked in cold water with mild detergent, **but only after all the electronics have been disconnected**. This includes the interface box, the tilt sensor and the optical electronics board. **DO NOT** soak the electronics. **DO NOT** scrub, dry-clean or spin-dry the lycra part. To dry the lycra once it has been soaked, carefully put it down on a towel and allow it to dry. When the lycra has dried, carefully clean the front-ends of the optical fibers with a dry cotton bud before assembling the glove again.
- Q** Are left-handed gloves available? Are they priced the same as the right handed ones, and can I use a left and right-handed glove at the same time?
- A** Left-handed gloves are available. They are priced slightly higher than the right-handed ones because of lower production volumes. Left and right-handed gloves may be used simultaneously, provided you have two free serial ports for the gloves.
- Q** Can I use four (or more) gloves on one machine at the same time?
- A** 5DT just loves people like you! The number of gloves is limited by the number of serial ports on your computer. Multiport cards are available that have up to eight serial ports on them. It is also possible to obtain a USB (Universal Serial Bus) device that has many RS 232 serial ports on it. The software supplied with the glove will work with any Win32 port setting from COM1 to COM8.
- Q** Is it possible to use the glove with a 6DOF tracker?
- A** Yes. You may mask or ignore the data from the built-in tilt sensor.
- Q** When I flex a finger, the output does not change but stays at the maximum value. What is the problem?
- A** Either one of the fibers has failed or the data glove has become uncalibrated. If, when flexing the relevant finger, the data stream remains saturated high, and does not change at all, it is likely that the fiber for that finger has broken. The glove will then have to be returned to the supplier (or 5DT) for repairs. If hardware calibration is necessary, please refer to Appendix G for detailed instructions.

- Q** The dynamic range of my glove is limited. When I flex my fingers, the output changes only slightly. What should I do?
- A** Your glove may need hardware calibration. Please refer to Appendix G for detailed instructions.

5.3 Support

If you experience problems or have complaints, suggestions or other comments, please feel free to contact your supplier (preferably via e-mail). Please have the following information available, or include it in your written correspondence:

1. Computer processor make and model (e.g. Pentium II 350)
2. Operating system and version
3. The symptoms of the problem and what was happening when the problem occurred
4. Can you reproduce the problem easily? Describe how
5. Actions taken by yourself to solve the problem

You may also contact 5DT directly. Please refer to our contact details in section 7.

Your feedback helps make this a truly great product.

6 Warranty Information

6.1 Thirty (30) Day Customer Satisfaction Guarantee

If, for any reason, you are disappointed with this product, please contact your supplier. If you are not completely satisfied, you will be granted a full refund once the product is returned undamaged. Unfortunately, shipping costs cannot be refunded.

6.2 One (1) Year Product Warranty

5DT warrants to the original purchaser of the 5DT Data Glove 5 or 5DT Data Glove 5-W that it will be free of defects in materials and workmanship for a period of one year from the original date of purchase. During the warranty period, 5DT will repair or replace (with a reconditioned unit) components that are defective.

Exclusions

The above warranty is provided for private use only and shall not apply to any commercial use of the product, including (but not limited to):

- Location based entertainment (LBE) applications
- Trade show demonstrations

This warranty shall not apply to defects resulting from the following:

- Misuse
- Improper or inadequate maintenance
- Unauthorized modification

6.3 Warranty Claim Instructions

Please use the following procedure if you require warranty service:

1. Contact your supplier to determine if you need to return the product. If your supplier is unable to determine this, contact 5DT directly. Do not return a product to your supplier or to 5DT **without first contacting them**.
2. Your supplier (or 5DT) will issue you with a Return Material Authorization (RMA) number. Do not return a product to your supplier or to 5DT without an RMA number.
3. Pack the items to be returned securely using the original packaging material (if possible). Please do not ship the glove in an envelope, use a cardboard box instead.
4. Please enclose the following:
 - Your original sales bill
 - Name, address, contact telephone/fax numbers
 - E-mail address
 - Reason for returning the item
 - RMA number
5. Mark your shipping container with the RMA number to expedite handling at your supplier or at 5DT.
6. Ship prepaid to your supplier or to 5DT.
7. When completing customs or courier documentation, please clearly indicate: "Unit returned for repairs under warranty".

5DT is not responsible for any damage that may occur during shipping. Shipping charges to 5DT are your responsibility. COD shipments will not be accepted by 5DT.

7 About 5DT

5DT <Fifth Dimension Technologies> is a high technology company specializing in Virtual Reality (VR). 5DT develops, produces and distributes affordable virtual reality hardware, software and systems. 5DT can also develop custom systems for all your VR needs.

5DT's focus is Virtual Reality Training Systems and Virtual Reality Peripherals.

The Virtual Reality hardware currently produced by 5DT includes:

- 5DT Data Glove 5 (Right and left)
- 5DT Data Glove 5-W (Wireless, right and left)
- 5DT Data Glove 16 (Right and left)
- 5DT Data Glove 16-W (Wireless, right and left)
- 5DT Data Glove MRI
- 5DT Head Mounted Display (HMD)
- 5DT 3-DOF Orientation Tracker
- 5DT Space Controller

Some of the Virtual Reality software and technology demonstrators that have been developed by 5DT include:

- Continuous Miner Training Simulator (Mechanized Coal Mining)
- High Voltage Yard Training Simulator
- High Voltage Line Inspection Training Simulator
- Air Traffic Control (ATC) Training Simulator
- Exposure Treatment Phobia Simulator
- Gastroscope Training Simulator
- Crane Operator Training Simulator
- VR FLO VIZ (Virtual Wind Tunnel)
- VR FLIGHT VIZ (Tactical Training Simulator for air combat)
- Integrated Virtual Battlefield
- Rocket Launcher Training Simulator
- Fiber Guided Video Missile Training System
- Landscape Generation and Real-time Rendering Technology
- Unmanned Aerial Vehicle (UAV) Training Simulator

5DT also produces multimedia software. Some of our existing products include:

- High Voltage Line Inspection Training System
- High Voltage Line Repair Training System
- High Voltage Line Visualization System
- Gastroenterology Training System

Most of our systems may be customized to suit specific end-user requirements.

Some of the systems currently under development at 5DT:

- Virtual Binoculars
- Bronchoscope Training Simulator
- Attack Helicopter Tactical Training Simulator

Advance information on these systems may be supplied on request.

5DT Head Office

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Appendix A - Hardware Specifications

- MATERIAL:** Black stretch lycra
- FLEXURE RESOLUTION:** 8-bit (256 positions) for each finger
- TILT ACCURACY:** 0.5°
(-60° to +60° linear range, 8-bit)
- BEND SENSORS:** Proprietary fiber optic based flexor technology. 1 sensor per finger.
- COMPUTER INTERFACE:** Standard glove:
RS 232 (3-wire)
GND, TX, RX
(RTS used in mouse emulation mode)
19200 bps (full duplex)
8 data bits, 1 stop bit, no parity
- Wireless glove:
RS 232 (2-wire)
GND, TX
9600 bps (transmit only)
8 data bits, 1 stop bit, no parity
- POWER SUPPLY:** Maximum 150 mA @ 9 V DC
Center positive DC power connector
- SAMPLING RATE:** With the standard glove, the full hand (5 fingers, pitch and roll) may be sampled at up to 200 samples per second. With the wireless glove, the full hand may be sampled at up to 100 samples per second.
- TRANSMISSION FREQUENCY:** Right-handed wireless glove:
418 MHz
- Left-handed wireless glove:
433.92 MHz
- TYPICAL WIRELESS RANGE:** Up to 30m

Due to a program of continuous improvement, these specifications are subject to change without prior notice.

Appendix B - Interface Cable Technical Details

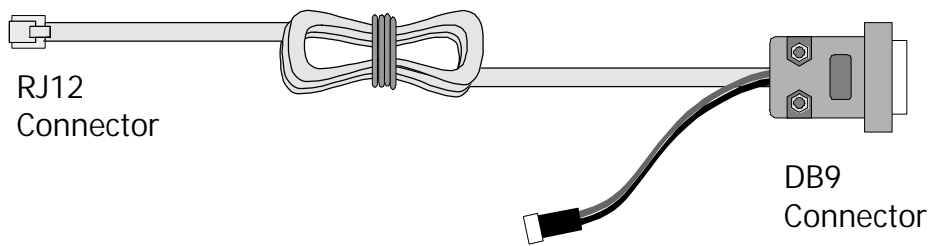


Figure 14 – The interface cable

RJ12 connector (glove side)

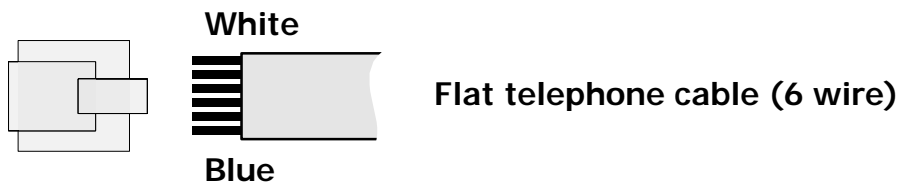


Figure 15 – RJ12 Connector

DB9 Connector (Computer Side)

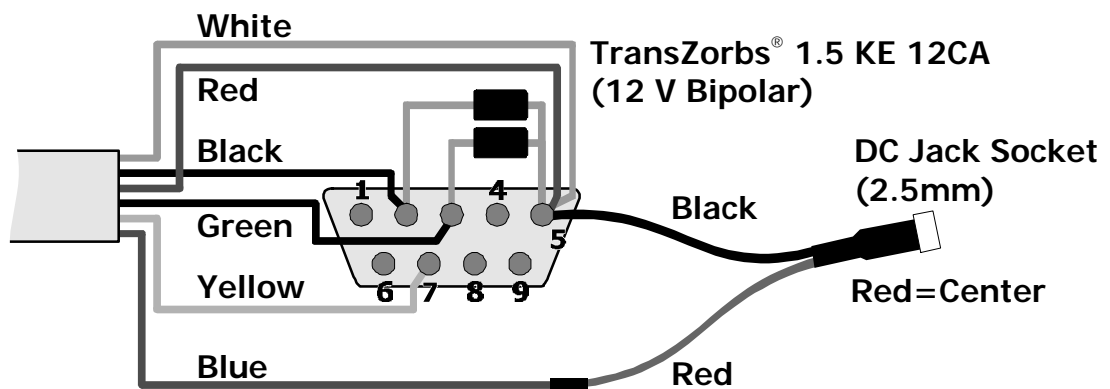


Figure 16 – DB9 Female Connector

DB9 Pins Used:

- 2 – RD
- 3 – TD
- 5 – GND
- 7 – RTS (only for mouse emulation mode)

Appendix C - Serial Port Interface Protocol

The data glove is connected to the RS 232 port of the computer. The standard 5DT Data Glove 5 can receive commands from the computer, and it responds to these commands by sending the necessary data. The following information is for the standard glove. The wireless 5DT Data Glove 5-W is a transmit-only device as it does not respond to any commands sent to it. Please refer to section C4 for the protocol of the wireless glove.

C.1 Communications

The 5DT Data Glove starts up in command mode. This mode has the following serial settings:

- 19200 bits per second
- 8 data bits, 1 stop bit, no parity
- Hardware handshaking: none

The serial link only utilizes the TX, RX and GND lines. The RTS line is only used when the glove is in mouse emulation mode.

The glove has a 1-byte input buffer. It does not detect buffer overflow, and does not transmit any signals to state that the buffer is full. If the buffer should overrun, the extra data will be discarded.

C.2 Command summary for the 5DT Data Glove 5

- | | HEX | ASCII |
|--|---|--------------------------------------|
| • Reset glove to command mode | | |
| Send: | <code>0x41</code> | <code>A</code> |
| Receive: | <code>0x55</code> | <code>U</code> |
| This is called the reset command . | | |
| • Test serial I/O | | |
| Send: | <code>0x42</code> <code>testbyte</code> | <code>B</code> <code>testbyte</code> |
| Receive: | <code>testbyte</code> | |
| • Set report data mode | | |
| Send: | <code>0x43</code> | <code>C</code> |
| Receive: | <code>gdata</code> | |
| While in report data mode, send the reset command to return to command mode. Any other byte sent to the glove will result in the <code>gdata</code> packet being returned. | | |
| • Set data stream mode | | |
| Send: | <code>0x44</code> | <code>D</code> |
| Receive: | <code>gdata</code> <code>gdata</code> ... | |

While in data stream mode, send the reset command to return to command mode. Any other byte sent to the glove will be ignored.

HEX

ASCII

- Set mouse emulation mode

Send: `0x45` `E`
Receive: `mdata` `mdata` ...

In mouse emulation mode the transmit speed is adjusted as follows:

1200 bits per second

7 data bits, 1 stop bit, no parity

The receive speed **remains the same**. Send the reset command at the normal speed (19200 bps, 8 data bits) to return command mode. Any other byte sent to the glove will be ignored.

- Set high-speed mouse emulation mode

Send: `0x46` `F`
Receive: `mdata` `mdata` ...

This mode is the same as mouse emulation mode, but the transmit speed is not changed (the transmit and receive speed are the same: 19200 bps, 8 data bits). Send the reset command to return to command mode. Any other byte sent to the glove will be ignored.

- Request glove information

Send: `0x47` `G`
Receive: `ginfo`

- Upload gesture settings

Send: `0x48` `gestures` `H` `gestures`
Receive: `0x55` `U`

- Download gesture settings

Send: `0x49` `I`
Receive: `gestures`

Refrain from using non-documented commands. Although some commands may produce certain results, 5DT may change such commands without prior notice. Future devices may return longer or different data strings, so you should examine the capability word carefully.

C.3 Packet structure

The following packets may be sent or received by the glove when the above commands are used:

`testbyte`

This can be any 8-bit value. To test the communication with the glove a random byte can be sent in the **Test Serial I/O** command. The communication is successful if the same byte is returned from the glove.

gdata

The measured flexure of the fingers and the measured pitch and roll of the tilt sensor are returned in this packet. The packet consists of 9 bytes and has the following structure:

Header **f1** **f2** **f3** **f4** **f5** **pitch** **roll** **checksum**

The **header** is always a byte with a value of **0x80** (128 decimal). On a right-hand glove, the flexure values are assigned as follows:

f1=thumb **f2**=index **f3**=middle **f4**=ring **f5**=little

On a left-hand glove, the flexure values are assigned as follows:

f1=little **f2**=ring **f3**=middle **f4**=index **f5**=thumb

Each flexure value has a decimal range of **0** to **255**, with a low value indicating an unflexed finger, and a high value indicating a flexed finger.

pitch and **roll** are byte values ranging from **0** to **255**. A value of 128 for either sensor indicates that the hand is untilted in that axis (center value).

mdata

This packet is emitted when the glove is in mouse emulation mode, at 1200 bps, 7 data bits. The packet is only sent when there is a change in the values. If there is no change then the packet is not sent. When the glove is in high-speed mouse emulation mode the packet is sent at 19200 bps, 8 data bits, and the most-significant bits are always zero.

The **mdata** packet consists of three bytes:

Bit:	6	5	4	3	2	1	0
Byte 1:	1	LB	RB	Y7	Y6	X7	X6
Byte 2:	0	X5	X4	X3	X2	X1	X0
Byte 3:	0	Y5	Y4	Y3	Y2	Y1	Y0

The LB bit indicates that the left button is down, and similarly the RB bit shows that the right button is down. The byte formed by **x₇₋₀** is the change in the horizontal position of the "mouse" cursor since the last packet. It is a two's complement number. The two's complement byte formed by **y₇₋₀** is the change in vertical position of the "mouse" cursor since the last packet.

Refrain from using non-documented commands. Although some commands may produce certain results, 5DT may change such commands without prior notice. Future devices may return longer or different data strings, so you should examine the capability word carefully.

ginfo

This packet contains information about the glove. It consists of 32 bytes divided as follows:

`header` `version-major` `version-minor` `capability-word-low`
`capability-word-high` `reserved` `ID-name`

`header` is always two bytes with a value of `0x42` and then `0x52` ("BR" in ASCII).

`version-major` is for example, the 1 in 1.04 (1 byte)

`version-minor` is for example, the 04 in 1.04 (1 byte)

`capability-word-low`

bit 0 is set if the glove is a right hand glove

bit 6 is set if the glove is a left hand glove

`capability-word-high`

bit 4 is set if pitch and roll measurements available

`reserved` is 10-bytes of reserved data.

`ID-name` is a 16-byte character array containing the name of the glove. If the length of the name is less than 16 bytes, it is padded with **NULL** characters (`0x00`).

gestures

This packet contains the threshold values used for gesture recognition, as well as the actual gestures assigned to single and double clicks of the left and right mouse buttons.

The packet is structured as follows:

`T1` `T2` `T3` `T4` `T5` `00`
`mask-left-button` `match-left-button`
`mask-left-dbl-click` `match-left-dbl-click`
`mask-right-button` `match-right-button`
`mask-right-dblclick` `match-right-dblclick`

`T1` to `T5` are the thresholds for the five fingers. On a right-hand glove they are in the order **thumb** → **little**, while on a left-hand glove they are in reverse order. If a sensor value for a specific finger is below the threshold value, then the finger is unflexed. If it is above the threshold value, then the finger is flexed.

The bits in the mask and match bytes are encoded as follows:

BIT NUMBER	RIGHT HAND GLOVE	LEFT HAND GLOVE
0	Little	Thumb
1	Ring	Index
2	Middle	Middle
3	Index	Ring
4	Thumb	Little
5 to 7	Not used	Not used

The way that corresponding bits from the mask and match bytes are set, specifies how that specific finger matches to a gesture. The variations can be summarized as follows:

MASK	MATCH	ACTION
0	0	This finger always matches
1	0	Match when the finger is flexed
1	1	Match when the finger is unflexed

A mask bit of 0 with a corresponding match bit of 1 means that the finger never matches. This combination is quite useless and in practice is never used.

The default gestures are as follows:

- Left button: Fist**
- Left double-click: Two Point**
- Right button: Not index (Middle, Ring & Little fingers flexed)**
- Right double-click: Little Point**

Please refer to Fig. 19 in Appendix E for gesture illustrations.

C.4 Wireless protocol

The wireless 5DT Data Glove 5-W is directly connected a transmitter unit that transmits the signals via a radio frequency (RF) link. The receiver unit detects the RF signals and sends them to the computer via a serial connection to the RS 232 port.

This mode has the following serial settings:

- 9600 bits per second
- 8 data bits, 1 stop bit, no parity
- Hardware handshaking: none

The serial link only utilizes the TX and GND lines, in other words the wireless glove is a transmit-only device. The receiving unit ignores all commands sent to it from the computer.

The glove continuously emits a glove data packet. This packet is similar to the packet sent by the standard glove, however one extra byte is added to the end of the packet:

`Header f1 f2 f3 f4 f5 pitch roll checksum cb`

The `header` is always a byte with a value of `0x80` (128 decimal).

`cb` is the capability byte of the wireless glove.

bit 0 is set if the glove is a right hand glove

bit 6 is set if the glove is a left hand glove

On a right-hand glove, the flexure values are assigned as follows:

`f1`=thumb `f2`=index `f3`=middle `f4`=ring `f5`=little

On a left-hand glove, the flexure values are assigned as follows:

`f1`=little `f2`=ring `f3`=middle `f4`=index `f5`=thumb

Each flexure value has a decimal range of `0` to `255`, with a low value indicating an unflexed finger, and a high value indicating a flexed finger.

`pitch` and `roll` are byte values ranging from `0` to `255`. A value of 128 for either sensor indicates that the hand is untilted in that axis (center value).

APPENDIX D - Glove Data Format (GDF)

Glove Manager is able to save the data received from the glove to a file for later processing. One of the supported file formats is called Glove Data Format (GDF). GDF is based on XML (Extensible Markup Language). This section describes the structure of the GDF files that Glove Manager generates.

The World Wide Web Consortium (W3C) recommendations for XML can be found at the following URL:

<http://www.w3.org/TR/REC-xml>

File Structure

The file is structured as a standard text file consisting of lines of characters separated by carriage-return / line-feed pairs (decimal ASCII value 13 and 10, respectively). The position of these CR/LF pairs is unimportant. It is also possible to use a single line-feed character instead of a CR/LF pair.

A GDF file begins with a *processing instruction*, which identifies it as an XML file. The declaration also specifies a standalone document:

```
<?xml version="1.0" standalone="yes"?>
```

The root element is the **log** element, starting with a **<log>** start-tag and ending with a **</log>** end-tag. It has a **class** attribute and a **datatype** attribute:

```
<log class="5DT Data Glove" datatype="Raw">
...
</log>
```

The **class** attribute should always be "5DT Data Glove", indicating that the file is a 5DT Data Glove Log File. The **datatype** attribute can be either "Raw" or "Scaled", and is used to determine what kind of data is stored in the file. "Raw" indicates that the data in the file is raw data, reported exactly as it has been received from the glove. "Scaled" means that the data in the file has been scaled (using the calibration information) before being written to disk.

The content of the **log** element consists of an optional **title** element and one or more **gdp** (glove data packet) elements:

```
<log ...>
<title>5DT Data Glove Log File</title>
...
<gdp ...> ... </gdp>
<gdp ...> ... </gdp>
<gdp ...> ... </gdp>
...
</log>
```

A **gdp** element has a **t** attribute, which indicates the time (in milliseconds) of the packet. The first packet will have a **t** attribute value of 0 (zero). The content of a **gdp** element is a set of optional sensor elements.

The names of the possible elements and their associated sensors are as follows:

- tf** Thumb finger flexure
- if** Index finger flexure
- mf** Middle finger flexure
- rf** Ring finger flexure
- lf** Little finger flexure
- pt** Pitch tilt
- rt** Roll tilt
- gst** Gesture

If a certain sensor element does not exist, the value of that sensor is assumed to be the same as the previous packet. Each element must consist of a start-tag and an end-tag with a value between the two tags. The possible range for the sensor values is 0 to 255 (inclusive).

A sample **gdp** element could look as follows:

```
<gdp t="25"><tf>55</tf><gst>Index Point</gst></gdp>
```

Appendix E – 5DT Data Glove Driver

1. Introduction

The 5DT Data Glove Driver provides access to the 5DT range of data gloves at an intermediate level.

The Windows 95/98/NT version is provided in the form of a C/C++ header (.h) file, a Microsoft Visual C++ library (.lib) file and a dynamic link library (.dll) file.

The Linux version is provided in form of a C/C++ header (.h) file, and a dynamic library (.so) file.

The driver functionality includes:

- Multiple instances
- Easy initialization and shutdown
- Basic (raw) sensor values
- Scaled (auto-calibrated) sensor values
- Calibration functions
- Basic gesture recognition
- Cross-Platform Application Programming Interface

2. Using the glove driver

The 5DT Data Glove Driver is easy to implement. Use the following guidelines:

2.1 Windows 95/98/NT

- i. Make sure that the header file `fglove.h`, the library file `fglove.lib` and the dynamic link library file `fglove.dll` reside in the current (application) directory, or somewhere that they can be found. The file `fglove.dll` may be copied into your Windows system directory.
- ii. Include the header file `fglove.h` in the application where necessary.
- iii. Add the library file `fglove.lib` to the link process.

There is also a debug version of the driver (`fgloved.lib`, `fgloved.dll`) which outputs debug messages to the debugger.

2.2 Linux

The driver requires the Linux Posix threads library `libpthread.so`, which is usually installed with Linux. The driver is linked to `libc6`.

2.2.1 Installing the library

The driver is a dynamic library file (`libfglove.so`) which must be installed somewhere where applications can find it. If you have root access to the system, the easiest method is to copy the file into the `/usr/lib` directory, e.g.:

```
# cp libfglove.so /usr/lib
```

If you do not have root access to the system, you should place the library somewhere in your home directory, and then set the `LD_LIBRARY_PATH` environment variable to include the full path of the directory in which you have placed the library. This will indicate to the dynamic library loader where to find the file. For example:

```
$ mkdir /home/yourhomedir/libs
$ cp libfglove.so /home/yourhomedir/libs
$ export LD_LIBRARY_PATH="/home/yourhomedir/libs"
```

In the above example, replace "yourhomedir" with your own home directory name.

2.2.2 Setting up access to the serial port

The 5DT Data Glove accesses the serial port using the standard Unix/Linux device files in the `/dev` directory. Applications that use the glove should typically give the user the option of specifying which device to check, such as `/dev/ttyS1`. It is recommended that you create a symbolic link `/dev/fglove` to your device file, e.g:

```
# cd /dev
# ln -s ttyS1 fglove
```

This may make the setup of applications easier should you need to change the port that the glove is connected to.

It is also required that the user of the glove has read/write access to the serial port device file. By default, normally only the root user has these rights. If non-root users on the system will be using the glove, the root user must grant access rights to the device file. For example, the following command will give everyone on the system full access to the serial port `/dev/ttyS1`:

```
# chmod 777 /dev/ttyS1
```

2.2.3 The header file

The header file (`fglove.h`) should be copied somewhere where your compiler can find it. If you have root access, the easiest is to copy it to `/usr/include`. If not, then just place the header file in the same directory as your application.

2.3 Sample source code

Sample source code that makes use of the glove driver is distributed with the driver.

3. Supported gloves

The glove driver supports all 5DT Data Gloves. The current version implements 18 possible sensors, and includes the roll and pitch sensors of the original 5DT Data Glove 5. The driver attempts to map values to all sensor outputs. If it is unable to do so the sensor value defaults to a sensible value. This value can be adjusted by forcing a specific value. To the application programmer the driver therefore appears the same regardless of the type of glove that is connected.

3.1 Sensor mappings for the 5DT Data Glove 5

The sensors on the 5DT Data Glove 5 are positioned as in Fig. 17.

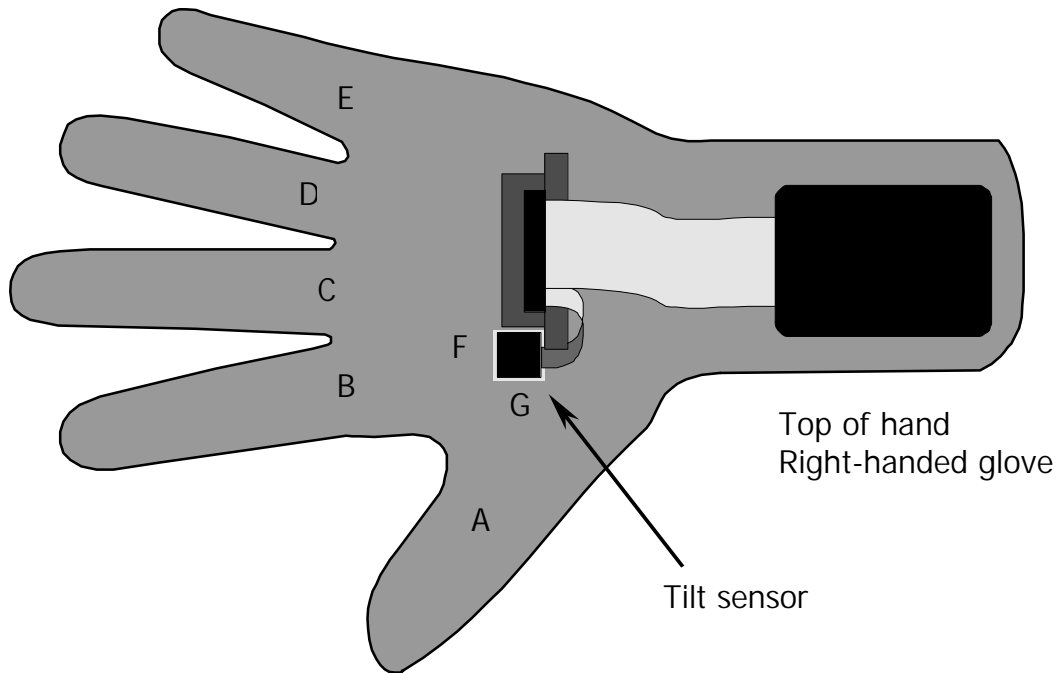


Figure 17 - Sensor positions for the 5DT Data Glove 5

<i>Sensor</i>	<i>Driver Index</i>	<i>Sensor</i>	<i>Description</i>
A	0,1*		Thumb flexure
B	3,4*		Index finger flexure
C	6,7*		Middle finger flexure
D	9,10*		Ring finger flexure
E	12,13*		Little finger flexure
F	16		Pitch angle of tilt sensor
G	17		Roll angle of tilt sensor

Table 2 - Sensor mappings for 5DT Data Glove 5

* Both these driver sensor indices will return the same value when the 5DT Data Glove 5 is used.

3.2 Sensor mappings for the 5DT Data Glove 16

The sensors on the 5DT Data Glove 16 are positioned as in Fig. 18

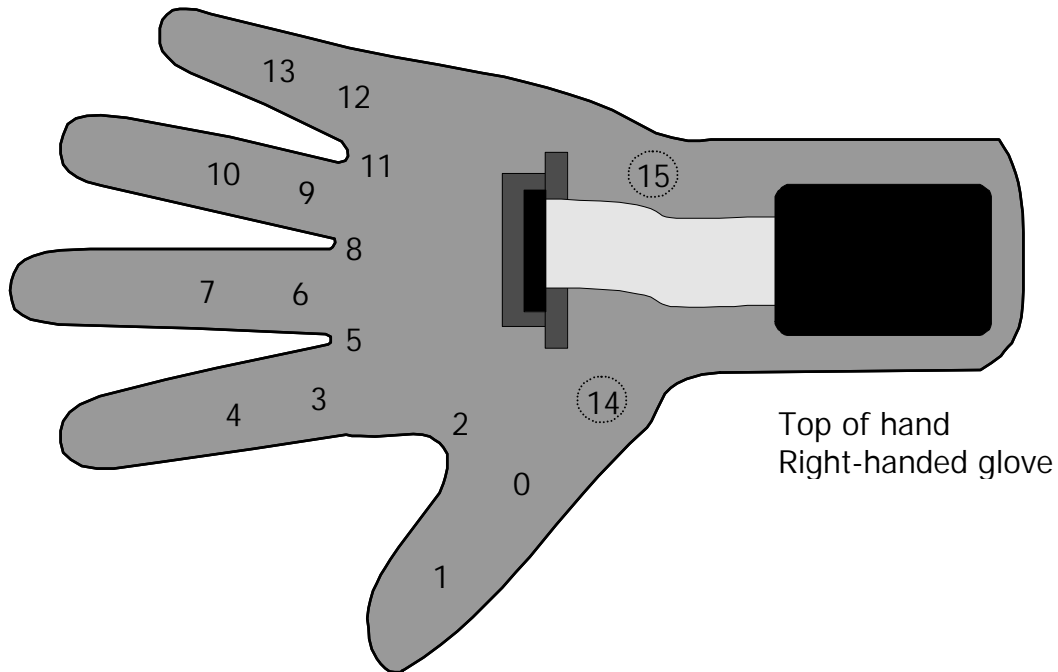


Figure 18 - Sensor mappings for the 5DT Data Glove 16

<i>Sensor</i>	<i>Driver Index</i>	<i>Sensor</i>	<i>Description</i>
0	0		Thumb flexure (lower joint)
1	1		Thumb flexure (second joint)
2	2		Thumb-index finger abduction
3	3		Index finger flexure (at knuckle)
4	4		Index finger flexure (second joint)
5	5		Index-middle finger abduction
6	6		Middle finger flexure (at knuckle)
7	7		Middle finger flexure (second joint)
8	8		Middle-ring finger abduction
9	9		Ring finger flexure (at knuckle)
10	10		Ring finger flexure (second joint)
11	11		Ring-little finger abduction
12	12		Little finger flexure (at knuckle)
13	13		Little finger flexure (second joint)
14	14		Thumb translation [not yet implemented]
15	15		Wrist flexure [not yet implemented]

Table 3 - Sensor mappings for 5DT Data Glove 16

4. Function reference

The following functions are provided by the driver:

fdGlove *fdOpen(char *pPort)

Initializes the glove device on the specified port.

Return value

Returns a pointer to the glove device (`fdGlove *`). NULL is returned if an error occurred.

Parameter

`pPort`

Pointer to a zero terminated ASCII string containing the name of the communication port. Valid values on Windows range from "COM1" to "COM8". Unix/Linux port names will differ.

Remarks

Do not attempt to alter the contents of the returned pointer directly, use the functions provided instead.

int fdClose(fdGlove *pFG)

Frees the glove device and communications port.

Return value

Returns nonzero if successful, zero if an error occurred.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

It is important to call this function when you are finished using the glove.

int fdGetGloveHand(fdGlove *pFG)

Obtains the handedness (left or right handed) of the glove.

Return value

Returns either `FD_HAND_LEFT` or `FD_HAND_RIGHT`, as defined by the enumerated type `EfdGloveHand`.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

None.

int fdGetGloveType(fdGlove *pFG)

Obtains the type of the currently connected glove.

Return value

Returns one of `FD_GLOVENONE`, `FD_GLOVE7`, `FD_GLOVE7W`, `FD_GLOVE16` or `FD_GLOVE16W`, as defined by the enumerated type `EfdGloveTypes`.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

`FD_GLOVE7` and `FD_GLOVE7W` refer to the original 5+2 (tilt angles) sensor glove (5DT Data Glove 5). The `w` suffix indicates a wireless model. `FD_GLOVE16` and `FD_GLOVE16W` refer to the 16 sensor glove. In order to accommodate both glove types the `fdGetNumSensors()` function currently returns 18 sensors. The additional two sensors are defined as the original tilt angles that are not present in the 16-sensor glove. See the description of `fdGetNumSensors()` for more details.

int fdGetNumSensors(fdGlove *pFG)

Obtains the number of available sensors values the driver can make available.

Return value

Returns the number of sensors. Currently it is fixed at 18, but future driver releases may differ.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

Although the 5-sensor glove can measure only average flexure, the driver will attempt to fill in missing values. The number of sensors returned can therefore be of a higher dimension. The enumerated type `EfdSensors` defines the finger mapping for each sensor.

void fdGetSensorRawAll(fdGlove *pFG, unsigned short *pData)

Obtains the most recent raw sensor values from the currently connected glove.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

pData

Pointer to an array of 16-bit integers that will contain the raw sensor values. The size of the array must always match the value returned by `fdGetNumSensors()`.

Remarks

Currently the raw sensor samples are all 12 bit unsigned values. The range is therefore from 0 to 4095. Note that this is not the dynamic range of the sensors. There can be severe offset values associated with each sensor. The enumerated type `EfdSensors` defines the finger mapping for each sensor.

unsigned short fdGetSensorRaw(fdGlove *pFG, int nSensor)

Obtains the most recent raw sensor value for a specific sensor from the currently connected glove.

Return value

Returns a 16-bit integer. See `fdGetSensorRawAll()` for details.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

nSensor

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

Remarks

The enumerated type `EfdSensors` defines the finger mapping for each sensor.

void fdSetSensorRawAll(fdGlove *pFG, unsigned short *pData)

Forces the raw value for all the sensors.

Return value

None.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

pData

Pointer to an array of 16-bit integers that will contain the raw sensor values. The size of the array must always match the value returned by `fdGetNumSensors()`.

Remarks

Currently the raw sensor samples are all 12 bit unsigned values. The range is therefore from 0 to 4095. The enumerated type `EfdSensors` defines the finger mapping for each

sensor. Forcing a sensor value will result in a raw and scaled output other than the default zero. Values that can be mapped will be overwritten, rendering the forced value void.

```
void fdSetSensorRaw(fdGlove *pFG, int nSensor, unsigned short nRaw)
```

Forces the raw value for a specific sensor.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

`nRaw`

16 bit raw value of the sensor. If the sensor is unmapped, the scaling calculations will proceed as normal.

Remarks

The enumerated type `EfdSensors` defines the finger mapping for each sensor. This function is only useful for sensors that cannot be mapped by a specific hardware device. Forcing a sensor value will result in a raw and scaled output other than the default zero. Values that can be mapped will be overwritten, rendering the forced value void.

```
void fdGetSensorScaledAll(fdGlove *pFG, float *pData)
```

Obtains the most recent scaled (auto-calibrated) sensor values from the currently connected glove.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`pData`

Pointer to an array of floating point numbers that will contain the scaled sensor values. The size of the array must always match the value returned by `fdGetNumSensors()`.

Remarks

The sensor range is a value from zero to the value defined by the `fdSetSensorMax()` and `fdSetSensorMaxAll()` functions. The glove driver defaults to a range of [0...1].

The automatic calibration process is described in section 6. The enumerated type `EfdSensors` defines the finger mapping for each sensor.

float fdGetSensorScaled(fdGlove *pFG, int nSensor)

Obtains the most recent scaled (auto-calibrated) value for a specific sensor from the currently connected glove.

Return value

Returns a floating point sensor value.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

Remarks

The sensor range is a value from zero to the value defined by the `fdSetSensorMax()` and `fdSetSensorMaxAll()` functions. The glove driver defaults to a range of [0...1]. The automatic calibration process is described in section 6. The enumerated type `EfdSensors` defines the finger mapping for each sensor.

int fdGetNumGestures(fdGlove *pFG)

Obtains the number of available gestures that can be recognized by the glove driver.

Return value

Returns the number of available gestures. Currently 16 different gestures are supported. Refer to section 5 for details.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

None.

int fdGetGesture(fdGlove *pFG)

Obtains the current gesture being performed.

Return value

Returns the current gesture being performed. Refer to section 5 for details.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

None.

```
void fdGetCalibrationAll(fdGlove *pFG, unsigned short *pUpper,
unsigned short *pLower)
```

Obtains the current auto-calibration settings of the driver.

Return value

None.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

pUpper and pLower

Arrays of 16 bit unsigned integers that will contain the maximum and minimum raw sensor values. The size of each array must always match the value returned by `fdGetNumSensors()`. Refer to section 6 for details.

Remarks

None.

```
void fdGetCalibration(fdGlove *pFG, int nSensor, unsigned short
*pUpper, unsigned short *pLower)
```

Obtains the current auto-calibration settings of the driver for a specific sensor.

Return value

None.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

nSensor

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

pUpper and pLower

Pointers to 16 bit unsigned integers containing the maximum and minimum raw sensor values. Refer to section 6 for details.

Remarks

None.

```
void fdSetCalibrationAll(fdGlove *pFG, unsigned short *pUpper,  
unsigned short *pLower)
```

Resets the current auto-calibration settings of the driver to user defined values.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`pUpper` and `pLower`

Arrays of 16 bit unsigned integers containing the maximum and minimum raw sensor values. The size of each array must always match the value returned by `fdGetNumSensors()`. Refer to section 6 for details.

Remarks

For unmapped sensors it would be sensible to set the upper and lower calibration settings above and below the raw value forced with `fdSetSensorRaw()` and `fdSetSensorRawAll()`.

```
void fdSetCalibration(fdGlove *pFG, int nSensor, unsigned short  
nUpper, unsigned short nLower)
```

Resets the current auto-calibration settings of the driver for a specific sensor to user defined values.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

`nUpper` and `nLower`

16 bit unsigned integers containing the maximum and minimum raw sensor values. Refer to section 6 for details.

Remarks

For unmapped sensors it would be sensible to set the upper and lower calibration settings above and below the raw value forced with `fdSetSensorRaw()` and `fdSetSensorRawAll()`.

void fdResetCalibration(fdGlove *pFG)

Resets the internal auto-calibration settings of the driver to appropriate default values.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

Remarks

This function is similar to the `fdSetCalibrationAll()` function with each of the upper and lower calibration array values set to 0 and 4095 respectively. This function, or any of the other calibration functions, should be called whenever the application starts up or the glove changes users during run-time. For unmapped sensors the upper and lower calibration values are set to 4095 and 0 respectively, which is the *inverse* of the auto-calibration settings.

void fdGetSensorMaxAll(fdGlove *pFG, float *pMax)

Obtains the maximum scaled value for each sensor.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`pMax`

Array of floating point values that will contain the maximum scaled sensor values. The size of the array must always match the value returned by `fdGetNumSensors()`.

Remarks

The glove driver defaults to a maximum scaled value of 1 for each sensor.

float fdGetSensorMax(fdGlove *pFG, int nSensor)

Obtains the maximum scaled value for a specific sensor.

Return value

Returns the maximum scaled values of the sensor.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being queried. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

Remarks

The glove driver defaults to a maximum scaled value of 1 for each sensor.

```
void fdSetSensorMaxAll(fdGlove *pFG, float *pMax)
```

Sets the maximum scaled value for each sensor.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`pMax`

Array of floating point values that contains the maximum scaled sensor values. The size of the array must always match the value returned by `fdGetNumSensors()`.

Remarks

The glove driver defaults to a maximum scaled value of 1 for each sensor.

```
void fdSetSensorMax(fdGlove *pFG, int nSensor, float fMax)
```

Sets the maximum scaled value for a specific sensor.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

`fMax`

A floating point value that contains the maximum scaled sensor value.

Remarks

The glove driver defaults to a maximum scaled value of 1 for each sensor.

```
void fdGetThresholdAll(fdGlove *pFG, float *pUpper, float *pLower)
```

Obtains the current gesture recognition threshold settings of the driver.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`pUpper` and `pLower`

Arrays of floating point numbers that will contain the maximum and minimum threshold values. The size of each array must always match the value returned by `fdGetNumSensors()`. Refer to section 6 for details.

Remarks

None.

```
void fdGetThreshold(fdGlove *pFG, int nSensor, float *pUpper, float *pLower)
```

Obtains the current gesture recognition threshold settings of the driver for a specific sensor.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being queried. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

`pUpper` and `pLower`

Pointers to floating point numbers that will contain the maximum and minimum threshold values. Refer to section 6 for details.

Remarks

None.

```
void fdSetThresholdAll(fdGlove *pFG, float *pUpper, float *pLower)
```

Sets the current gesture recognition threshold settings of the driver.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`pUpper` and `pLower`

Arrays of floating point numbers that contains the maximum and minimum threshold values. The size of each array must always match the value returned by `fdGetNumSensors()`. Refer to section 6 for details.

Remarks

None.

```
void fdSetThreshold(fdGlove *pFG, int nSensor, float fUpper, float fLower)
```

Sets the current gesture recognition threshold settings of the driver for a specific sensor.

Return value

None.

Parameters

`pFG`

Pointer to a glove device. This is the value returned by `fdOpen()`.

`nSensor`

Index of the sensor that is being set. The value must lie in the range given by the enumerated type `EfdSensors`, or alternatively from zero to the value returned by `fdGetNumSensors()` minus one.

`fUpper` and `fLower`

Floating point numbers that contain the maximum and minimum threshold values. Refer to section 6 for details.

Remarks

None.

```
void fdGetGloveInfo(fdGlove *pFG, unsigned char *pData)
```

Obtains the information data block of the currently connected glove.

Return value

None.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

pData

Array of 32 bytes that will contain the information data.

Remarks

The information data is specified in the glove user's manual. The size of the information block is always 32 bytes.

```
void fdGetDriverInfo(fdGlove *pFG, unsigned char *pData)
```

Obtains the information data block of the driver.

Return value

None.

Parameters

pFG

Pointer to a glove device. This is the value returned by `fdOpen()`.

pData

Array of 32 bytes that will contain the information data.

Remarks

The information data is a zero terminated string that contains driver information. The size of the information block is always 32 bytes.

5. Gesture definitions

The currently defined set of gestures is comprised of binary open/close configurations of the fingers excluding the thumb. There are $2^4 = 16$ such possible combinations. Gesture number 0 is defined as all the fingers (excluding the thumb) being closed, and gesture number 15 as all the fingers open. The index finger indicates the least significant bit. For example, the index finger point gesture will therefore be number 1, and the little finger point gesture number will be 8. An invalid (unrecognizable) gesture is defined as the value -1.

A scaled sensor value of higher than the upper threshold setting will indicate a closed finger, while a scaled sensor value of lower than the lower threshold setting will indicate an open finger. A value in-between is invalid and will result in an invalid gesture. In the case of multiple finger joint angle measurements (such as the 16 sensor glove), the maximum of the individual joint sensor values is taken to obtain a closed gesture and the minimum to obtain an open gesture. Closed gestures take precedence, in other words, bending only one joint of a finger will count as a closed gesture.

The built-in gesture recognition capabilities of the glove driver is limited in scope and user independence. High level gesture recognition algorithms that rely on training sequences are suggested for advanced applications.

Finger:	Little	Ring	Middle	Index		
5DT Data Glove 5 sensor:	E	D	C	B		
5DT Data Glove 16 sensor:	12,13	9,10	6,7	3,4		
Driver sensor index:	12,13 [#]	9,10 [#]	6,7 [#]	3,4 [#]		

Gesture Number	Flexure (0=flexed, 1=unflexed)				Gesture Description	Fig.
0	0	0	0	0	Fist	19.0
1	0	0	0	1	Index finger point	19.1
2	0	0	1	0	Up yours	19.2
3	0	0	1	1	Two finger point	19.3
4	0	1	0	0	Ring finger point	19.4
5	0	1	0	1	Ring index point	19.5
6	0	1	1	0	Ring middle point	19.6
7	0	1	1	1	Three finger point (or not little point)	19.7
8	1	0	0	0	Little finger point	19.8
9	1	0	0	1	Howzit	19.9
10	1	0	1	0	Little middle point	19.10
11	1	0	1	1	Not ring finger point	19.11
12	1	1	0	0	Little ring point	19.12
13	1	1	0	1	Not up yours	19.13
14	1	1	1	0	Not index finger point	19.14
15	1	1	1	1	Flat hand	19.15

Table 4 - Gesture definition scheme as implemented for the 5DT Data Glove Driver

[#] When the 5DT Data Glove 5 is used, both these driver sensor indices will return the same value.

When the 5DT Data Glove 16 is used, the driver sensor indices will return different values. The maximum of the two values will be used to test for a flexed (closed) gesture, and the minimum value of the two will be used to test for an unflexed (open) gesture.

The following gestures are currently defined (right hand shown):



0) Fist



1) Index finger point



2) Up Yours (Middle finger point)



3) Two finger point



4) Ring finger point



5) Ring-index finger point



6) Ring-middle finger point



7) Three finger point (or not little finger point)



8) Little finger point



9) Howzit (index and little finger point)



10) Little-middle finger point



11) Not ring finger point



12) Little-ring finger point



13) Not up yours



14) Not index finger point



15) Flat hand

Figure 19 - Gesture Illustrations

6. Auto-calibration

The driver can provide sensor outputs in an automatic, linearly calibrated fashion. During every update, the raw value read from the sensor is compared to the current minimum and maximum raw values (raw_{min} and raw_{max}) as set by the functions `fdSetCalibrationAll()`, `fdSetCalibration()` or `fdResetCalibration()`. If the current minimum and maximum values are exceeded, they are overwritten. The upper and lower calibration values are therefore continuously pushed "outwards". The normalized output is given by the first order equation

$$out = \frac{raw_{val} - raw_{min}}{raw_{max} - raw_{min}} \cdot Max, \quad (F-1)$$

which is in $[0...Max]$. The value of Max is set by the functions `fdSetSensorMaxAll()` and `fdSetSensorMax()`. Doing a few flexing movements with the hand quickly sets the operating values for raw_{min} and raw_{max} , and calibrates the glove.

The auto-calibration process can be ignored by simply regarding only the raw sensor outputs. It would be up to the application developer to provide a suitable calibration process. Note that calibration is *mandatory*, especially with the 16 sensor glove which contains no hardware calibration possibilities (miniature preset potentiometers).

Appendix F – Software Calibration

When the 5DT Data Glove is calibrated in the factory, we try to obtain the largest possible dynamic range. The dynamic range is the difference between the maximum output value (flexed hand) and the minimum output value (flat hand).

$$\text{Dynamic Range} = \text{Value}_{max} - \text{Value}_{min} \quad (\text{F-2})$$

The dynamic range may differ when persons with different hand sizes use the glove. We therefore recommend that a software calibration routine be included with all glove applications/programs.

Software calibration normalizes the effect of different dynamic ranges for different hand sizes.

The software calibration routine should store the minimum and maximum values and scale the output for maximum dynamic range. For example, lets work through an example for the thumb (please refer to Fig. 8, section 3.3):

The minimum value is:	40	=	Value _{min}
The maximum value is:	206	=	Value _{max}
The dynamic range is:	206 – 40	=	166

To scale the measured values across the full dynamic range (256 values), one therefore has to perform the following operation:

$$\text{Value}_{scaled} = (\text{Value}_{measured} - \text{Value}_{min}) \times (255/\text{Dynamic Range}) \quad (\text{F-3})$$

For 40 this becomes $(40 - 40) \times (255/166) = 0$

For 206 this becomes $(206 - 40) \times (255/166) = 255$

This routine could also be implemented dynamically, where the glove calibrates itself while the user uses it. The routine is similar to the normal calibration scheme with the difference that the minimum and maximum values are updated continuously. The initial values for the minimum and maximum could be chosen as 126 and 128 respectively.

Please note that the 5DT Data Glove Driver includes a dynamic software calibration routine

Appendix G – Hardware Calibration

In some cases the glove may lose its factory hardware calibration, reducing the dynamic range significantly. This may be the result of movement of the opto-electronic transmitters and receivers, with respect to the fibers.

To determine whether hardware calibration is required, run Glove Manager (Section 3.1) and observe the trace view. Press *CTRL+R* to ensure that the raw (unscaled) data is shown. The trace view shows graphs of the flexure of each of the five fingers. When opening and closing your hand, these traces should vary from zero to maximum. If the total variation is less than a third of the maximum range, your glove needs hardware calibration.

Calibration

1. Open the black box containing the electronics

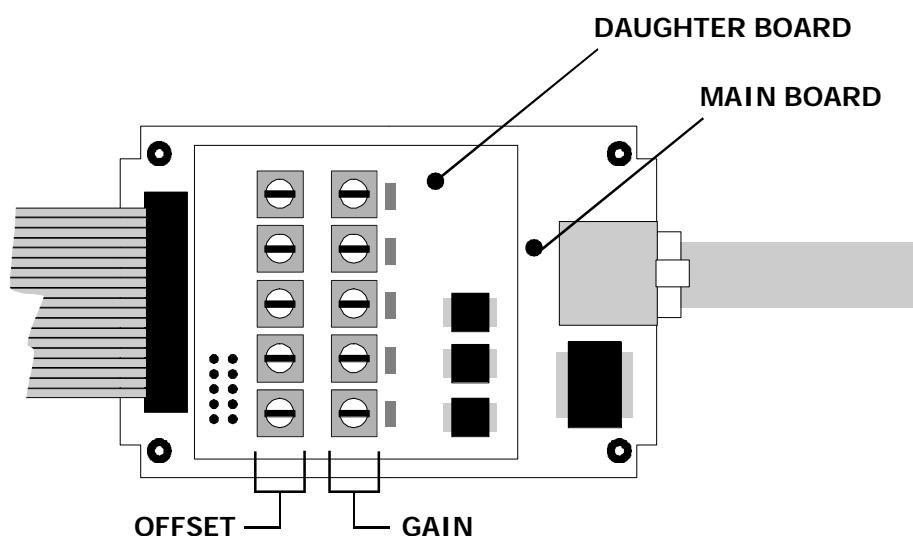


Figure 20 – Data Glove Main Board and Daughter Board

There are ten miniature potentiometers (pots) on the small daughter board. The five pots on the left hand side adjust the **offset** of the five fingers (i.e. they move the signal up and down). The five on the right hand side are for adjusting the **gain** of the five fingers (i.e. they make the signal larger or smaller). The two pots at the bottom are for the thumb, the next two are for the index finger, etc.

2. Run Glove Manager (*raw data mode!*), and observe the trace view.
3. Choose the finger that you would like to calibrate.
4. Set the gain for this finger to **minimum**. This is achieved by adjusting the right hand pot in a **clockwise** direction until it cannot rotate anymore. It is best to use a non-metallic (e.g. plastic) screwdriver for adjustment, to ensure that the screwdriver does not short-circuit the electronics should you slip.

- Repeatedly bend and unbend the finger you are calibrating. While doing this, adjust the offset until the waveform is in the center of the display. If you rotate the offset pot in a **clockwise** direction, the waveform will move **up**, and vice versa. Fig 21 shows an example of the centered waveform.



Figure 21 – Centered Waveform

- Continue bending your finger repeatedly, and now increase the gain of the signal until it **almost** reaches the maximum and minimum on the graph. You will find that by changing the gain, the offset will change slightly.
- Sometimes the graph will not be centered, and one side of the signal will **clip**. Fig 22 shows an example of this. If clipping occurs, adjust the offset to move the signal up or down. When the waveform is centered again, continue adjusting the gain.

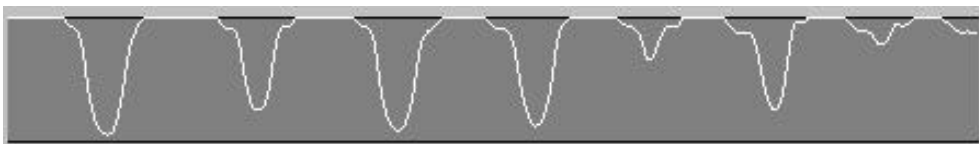


Figure 22 – Clipped Waveform

- Once the finger has been calibrated, it should look as in Fig 23 when you repeatedly flex and unflex your finger.

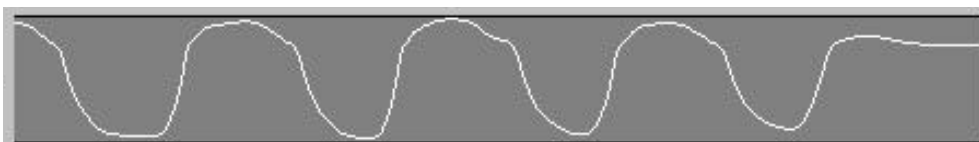


Figure 23 – Optimum Dynamic Range

- Be careful not to set the gain too high. Doing so will result in saturation, as shown in Fig. 24



Figure 24 – Waveform with gain too high

- Proceed with all the other fingers in the same manner