



phantom®
HAPTIC DEVICES

Premium 3.06DOF Device Guide

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Hardware usage guidelines are provided to assist the user in protecting the effectiveness and life of the device. They are not intended as recommendations for the prevention of repetitive stress injury, carpal tunnel syndrome or any other conditions, injuries or disorders; users should consult their own physicians. By using the Phantom device, the user acknowledges and agrees that Geomagic shall have no liability for any disorder, condition or injury arising from any use of the device.

Warning Do NOT open the Phantom device. Attempting to open or repair the device by anyone other than a certified authorized service center voids the manufacturer warranty and hardware maintenance contract.

Questions or Comments

If you have any questions for our technical support staff, please contact us at SensibleSupport@geomagic.com. You can also phone 1-888-736-7225 (U.S.A. only) or 1-781-939-7444 (International).

If you have any questions or comments about the documentation, please contact us at SensibleDocumentation@geomagic.com.



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Preface

About this Guide

The Phantom Premium 3.0 6DOF® Device Guide describes the process of installing the required device drivers for your new Phantom Premium haptic device and connecting the hardware device to your computer. You will also find information on how to use the device and other information about the device.

For the most current device information please visit our website at www.sensable.com.

We've worked extensively to ensure that the Phantom Premium 3.0 6DOF device and device drivers install and work smoothly. If you experience any problems in the installation or use of your device, please contact Customer Support (see inside cover for contact information).

Please note, if you are installing your device on a supported non-Microsoft® Windows OS, you will find additional information in a separate document that shipped with your software product.

Typographical Conventions

This guide uses the following typographical conventions:

Convention	Description	Example
<i>Italics</i>	First use of a new term; reference to another document or file.	A <i>Voxel</i> is...; see the <i>User Manual</i> .
Bold	Keywords, actual user input, or examples.	Click Ok .
Greater Than (>)	Indicates a menu pick, as in “select Options from the Tools menu”.	Tools>Options

PREFACE

1

Getting Started

This guide covers the currently shipping Phantom Premium haptic device. The information contained in this manual was current at the time of publication. Visit www.sensable.com for the latest information.

This chapter describes the following:

- The contents of the shipping box
- The Phantom Premium 3.0 6DOF haptic device
- System Requirements
- The proper handling of the Phantom Premium 3.0 6DOF haptic device

Contents of the Shipping Box

If you are purchasing a Phantom Premium 3.0 6DOF haptic device for the first time, in your shipping box you should find the following:

- **The Phantom Premium 3.0 6DOF haptic device:** The Phantom device uses high-fidelity force feedback to make it possible to touch and manipulate virtual objects.
- **The Phantom Premium 3.0 6DOF Device Guide:** Describes the process of connecting the haptic device as well as how to work with the device including proper handling, troubleshooting, and device specifications.
- **The Phantom Device Driver Installation Guide:** Describes the process of installing the device drivers.
- **Cables:** The cables used to connect the Phantom device are as follows; Parallel Port Cable, Power Cord, Encoder Signal Cable, Base Motor Power Cable 8-Pin, Gimbal Motor Power Cable 6-Pin, and an Audio Jack Cable.
- **Amplifier Box:** Connect cables, such as the Parallel Port Cable, to the Amplifier box.
- **Counterweight:**
- **Accessory Box:** Includes safety glasses, feet (4x), mounting screws, allen wrench, pinch end-effectors (thumb-pad and/or scissors, depending on your order).

If any items are missing, please call Customer Support at 1-888-736-7225.

The Phantom Premium Haptic Device

The Phantom Premium device enhances productivity and efficiency by enabling the most intuitive human/computer interaction possible, the ability to solve problems by touch.

The Phantom Premium 3.0 6DOF senses motion and provides force feedback in 6 degrees of freedom.

The Phantom Premium system's high fidelity force feedback senses motion providing the best, most realistic 3D Touch sensation for any application. You can feel the point of the stylus in all axes, and track its orientation. The Phantom Premium's design, compact footprint, and simple parallel port interface ensure quick installation and ease of use.

Features

- FCC and CE Certified
- Six degree-of-freedom positional sensing and force feedback
- Removable pinch end-effectors for end-user customization
- Constructed of metal components and injection-molded plastics

System Requirements

The Phantom Premium haptic device requires certain hardware and software components to be able to function properly. This sections describes the requirements for operating the Phantom Premium haptic device.

Note Visit www.sensable.com to get the latest and most complete system requirements information.

- An Intel® processor based personal computer (A minimum of Pentium® IV class processor is recommended) or select personal computer.
- IEEE 1284 EPP compliant parallel port interface; a Phantom Communication Converter (PCC - sold separately) and FireWire Card (requires IEEE-1394a-2000 compliant FireWire Port).
- The most current version of the Phantom Device Driver (PDD). See the *Phantom Device Driver Installation Guide* for specific PDD requirements.

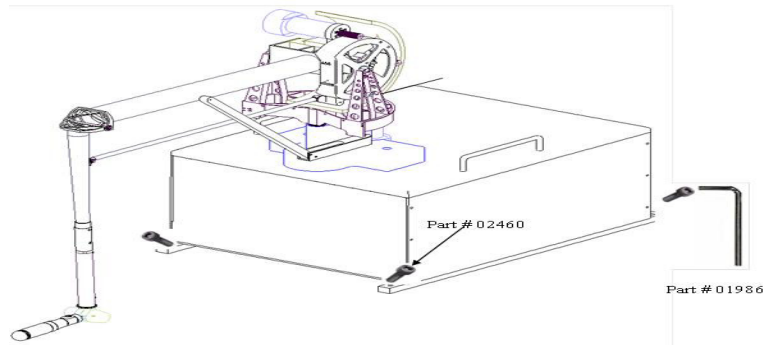
Proper Handling and Positioning of the Phantom Premium 3.0 6DOF Device

Warning Gripping and lifting the Phantom Premium 3.0 6DOF device improperly may damage it. To reduce the risk of damage, please follow the instructions below.

Handling the Phantom Premium 3.0 6DOF Device

Removing the Device from the Box The haptic device in its entirety (excluding cables), as shown in the image below, is bolted to the shipping pallet with four #1/4-20 Socket Head Screws (Part # 02460). These screws may be removed with a Hex Key (Part # 01986) which is supplied with the unit (inside the accessories box).

The haptic device in its entirety weighs about 60 pounds (27 Kilos). Exercise care when lifting the device by the handles, to place it on a desk or the intended workbench. Do not attempt to lift the device by using any other part as lifting means. Severe bodily injury and damage to the device may result.



Protecting the device from damage It is best to place the unit firmly on the desktop and away from edges to reduce the risk of damage to the device.

Positioning the Phantom Premium 3.0 6DOF Device

The correct placement of the device will vary from one user to another. You may want to experiment to find a placement that feels right for you.

- The device should be positioned so that you are comfortable when working with it.
- You should not feel any strain on your wrist or forearm when working with the device.
- If you are left-handed, you may find it easier to work with the mouse placed to the left of the keyboard.
- Remember to take breaks often to stretch your hands, wrists, and elbows.

2 GETTING STARTED

Proper Handling and Positioning of the Phantom Premium 3.0 6DOF Device

2

Installing the Phantom Premium Device

This chapter will describe, step by step, how to install the Phantom Premium 3.0 6DOF haptic device. The installation is done in two steps.

- Install the software, the Phantom Device Driver, that allows your computer to communicate with the Phantom Premium 3.0 6DOF device.
- Connect the hardware, the Phantom Premium 3.0 6DOF device, to your computer and power source.

Installing the Phantom Device Drivers

The Phantom Premium 3.0 6DOF device communicates with the computer through the Parallel port. To enable this, you must install a software driver, called the Phantom Device Driver (PDD), to control the communication.

Specific instructions for installing the PDD on Windows XP, Vista and Windows 7 operating systems can be found in the *Phantom Device Driver Installation Guide*. For installation instructions for other operating systems, see the additional documentation shipped with your device or software product or contact customer support

Note As with most other software packages, you must have administrator privileges on the machine in order to install software. If you are unfamiliar with installing software or do not have administrator privileges, please have your System Administrator execute the installation for you.

Connecting the Phantom Premium 3.0 6DOF Device

In this section you will setup the Phantom Premium 3.0 6DOF device and plug in all of the cables.

Note Exact appearance of your equipment may vary from that shown in the figures.

- 1 Shut down your computer.
- 2 Connect all cables except the AC Power Cable between the computer, Haptic Arm and The Amplifier Box.

- 3 Secure all connectors, where means are provided, to prevent them from falling off.
- 4 Plug in the AC Power Cable.
- 5 In the Control Panel, Under Phantom Configuration, select Premium Model 3.0 6DOF as the device.
- 6 Insert the round pin from the supplied power supply into the back of the Phantom Premium 3.0 6DOF device.

IMPORTANT

Geomagic uses only Parallel Port components that exceed the IEEE 1284 EPP implementation recommendations. Geomagic is not responsible for any damage that may result from using 3rd party cables.

Run Phantom Test to Verify Setup

In this section you will run the Phantom Test application to confirm that the device is properly connected and installed.

- 1 Select **Start>All Programs>Sensable>Phantom Test**.
- 2 If the device is properly connected and installed, the Phantom Test application will open and you will be in select mode. Gently move the Phantom arm and the Phantom test application will synchronously display the movement in the display window.

If the device is not properly connected, you will receive the following:

“The Phantom device named ‘Default Phantom’
could not initialize properly.”

If you encounter this error message first check to see that the Premium 3.0 6DOF is the selected device in the Phantom Configuration tool (Start>All Programs>Sensable). If you still encounter problems, reconnect the device and try again.

3

Using the Phantom Premium Device

This chapter will introduce you to working with the Phantom Premium 3.0 6DOF haptic device and the physical limits of the device's range of motion. It is important to understand these physical limitations so that you do not inadvertently damage the device by forcing it past its designed limits.

Working in 3D Space

We have become so accustomed to using a mouse to move around a computer monitor that we don't think twice as we move our hand around a desk to move the cursor on the computer screen. But there was a time not long ago when this seemingly simple task was not second nature; some even found it challenging and were often frustrated as they learned. If you are new to working in 3D digital space and haptics, working with the Phantom Premium 3.0 6DOF device may take a little getting used to. Understanding where objects are in 3D space may take some practice before you are able to move and manipulate objects with ease and certainty. Be patient with yourself.

Use Caution when Using the Phantom Premium Device

It is important to exercise care when working with force feedback devices:

- Read the manual thoroughly prior to using the Phantom Premium 3.0 6DOF.
- DO NOT put your face in the workspace of the Phantom Premium device. Safety glasses are recommended.
- DO NOT place your fingers inside the mechanism. At the installation site, access to motors and pulleys should be prevented.
- DO NOT run a haptics application unless the base is properly anchored to the desk or other surface as outlined in this manual.
- As a user of this product and software you accept full responsibility for assuring that the device is used in a safe and reasonable manner.

Physical Limits of the Device

The Phantom Premium 3.0 6DOF device has six degrees of motion provided by axis points. All the degrees of motion have physical limits. When you reach one of these limits you will feel a sudden stop; this is the mechanical stop designed into the device. Forcing the device past any of these stops risks damaging the device.

Take some time to become more familiar with the physical limits of the Phantom Premium 3.0 6DOF before using the device by moving the device through its full range of motion at each axis point.

- 1 First make sure the device is not active.
- 2 Grasp the end-effector, with the free end pointing toward you. Gently move the end-effector in all directions to feel the physical limits, mechanical stops.
- 3 In next steps you will perform macro movements. That is, you will move the device at the "body", "shoulder", and "elbow" of the Phantom Premium 3.0 6DOF device.
 - a Start with large-but gentle-movements. Beginning at the top, move the arm of the device left/right. The body, sometimes referred to as the turret, of the Phantom Premium 3.0 6DOF device will pivot until it reaches a physical limit. Again, do not try to force the device past any of the mechanical stops.
 - b Next, move the arm up/down. The primary movement will happen in the shoulder of the Phantom Premium 3.0 6DOF device.
 - c Next move it in/out with the primary movement happening in the elbow. When you reach a physical limit, you'll feel one of the device's mechanical stops. Don't force the device past any of these stops.
- 4 Next you perform micro movements further down the haptic device, moving the device at the end-effector, if one is in use:
 - a Holding the end-effector with one hand rotate left/right at the top of the yolk.
 - b Next pivot it up/down at the bottom of the yolk where it joins the end-effector.
 - c Finally gently twist the end-effector back/forth.

Now you should have an understanding of the range of motion of the Phantom Premium 3.0 6DOF device at each axis point and where its limits are.

Warning NEVER rotate the end-effector with the point facing you.

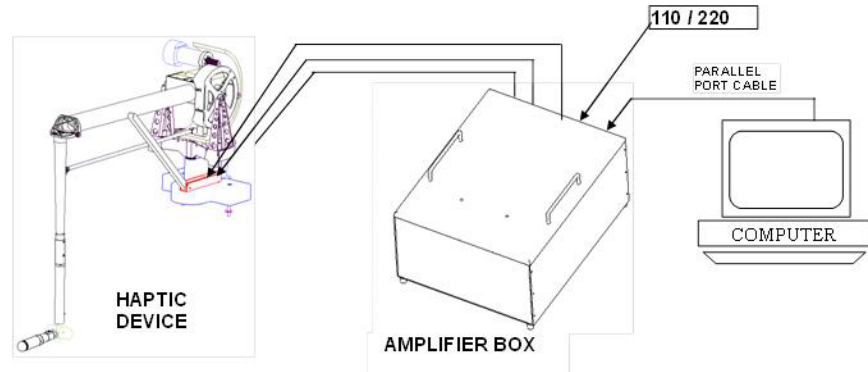
Understanding the System Components

These are the components that make up the Phantom Premium 3.0 6DOF System:

- The Phantom Premium 3.0 6DOF Arm (Haptic Device)
- The Amplifier Box
- Connecting Cables
 - Parallel Port Cable

- Power Cord
- Encoder Signal Cable (15 Pin-Dsub)
- Base Motor Power Cable (8-Pin Din)
- Gimbal Motor Power Cable (6-Pin Din)

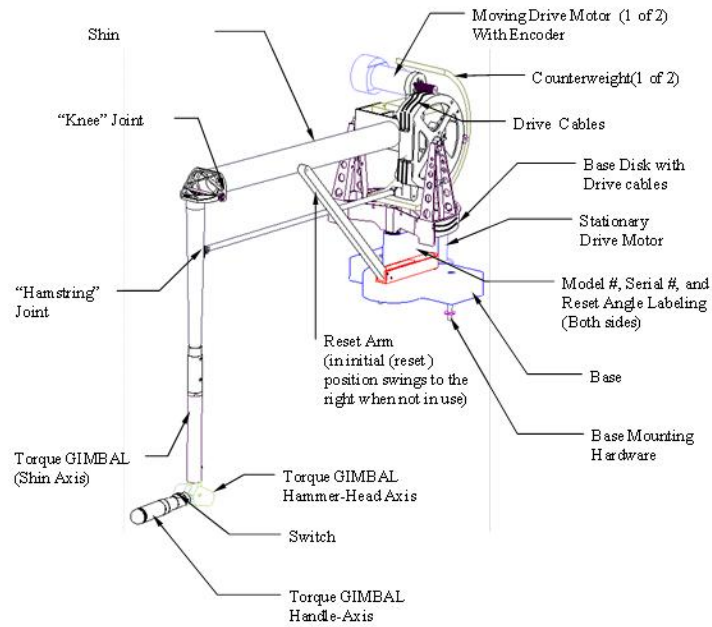
FIGURE 1.



The Phantom Premium 3.0 6DOF Arm:

The Phantom Premium 3.0 6DOF Arm (haptic device) consists of the following components as illustrated in the image below:

FIGURE 2.



The End Effector (Gimbal)

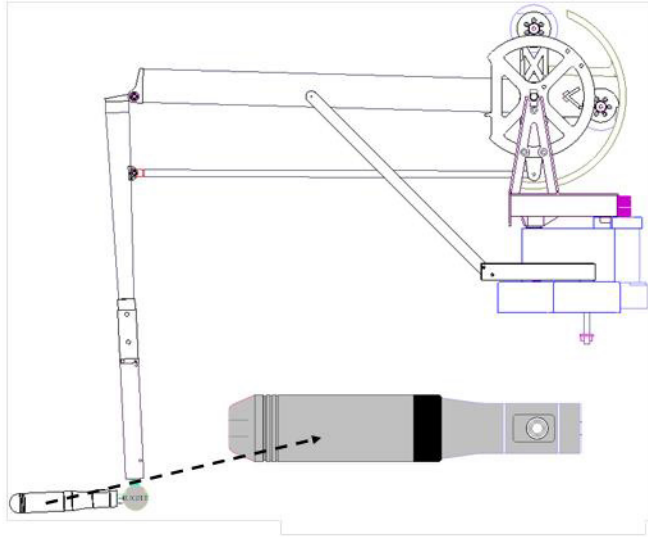
The Phantom Premium 3.0 6DOF is available with and an end-effector (Gimbal) that has 3 degrees of Torque feedback. This end-effector is installed at the factory and must be ordered as desired (cannot be modified by the user).

a Forward Handle Gimbal (Phantom 3.0-6DOF Part # 02605)

A momentary tactile switch is located on the Stylus as shown in the figure below. The stylus also has an auto-detect feature for safety (two shiny contact surfaces separated by an insulating ring). Phantom forces will operate only when the user properly grasps the stylus, thus allowing the stylus to detect user-presence (hand must make contact with both shiny surfaces).

The gimbal is also marked “LEFT” and “RIGHT.” Shown below is the “Forward Handle” configuration. When the handle is facing you, as in this case, the “RIGHT” marking on the Hammer-Head Axis should be to your right.

FIGURE 3.



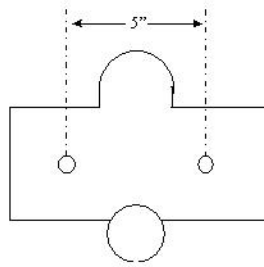
System Mounting Configurations

The Phantom Premium 3.0 6 DOF Haptic Device, as removed from the box, may be directly bolted onto a workbench by using the four #1/4-20 Socket Head Cap Screws that were securing it to the pallet, or with four shorter #1/4-20 Socket Head Cap Screws (3/4" long) provided in the accessories box.

If desired, the Phantom Premium 3.0 6 DOF Haptic Arm may be disassembled from the Amp Box by using the Hex Key provided to remove two #1/4-20 Socket Head Cap Screws that are securing it (Part # 01971). These two screws may be reused to bolt the Haptic Arm directly to a workbench. Nuts and washers are provided with the device. The Amp Box may then be placed under the bench or as desired by the user. The supplied cables are about 7 feet long.

Two mounting holes in the base are sized to accommodate 1/4-20 Socket Head Cap Screws and are positioned 5" (12.7 cm) apart as shown in the image below. The system comes with two 1.5" long, 1/4-20 Socket Head Cap Screws (Part # 01971) and two 3" long, 1/4-20 Socket Head Cap Screws (Part # 01988) with the necessary nuts (Part # 01972) and washers (Part # 01973).

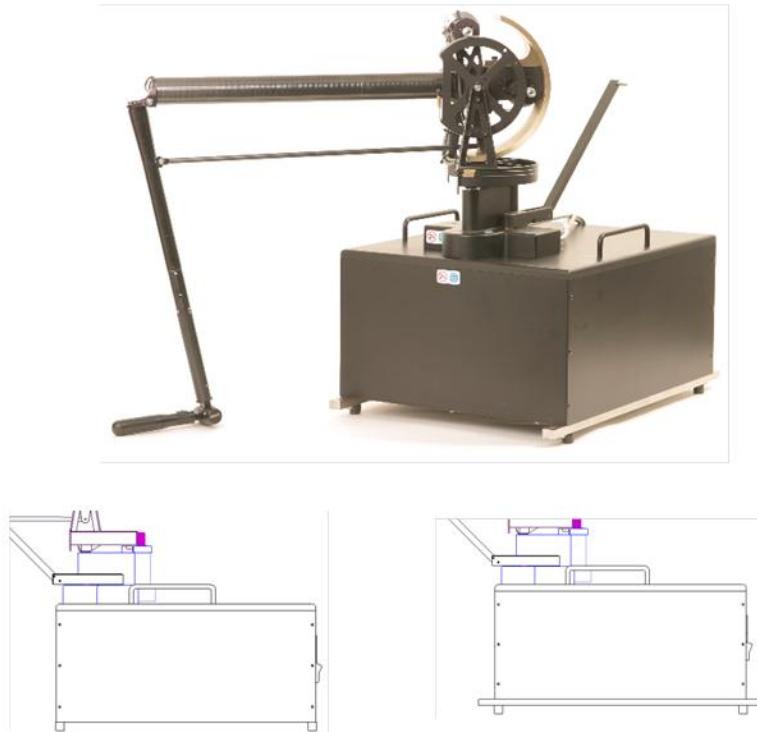
FIGURE 4.



The optimal mounting height in this Configuration is 10” (25 cm) above the plane of the workbench. This allows a seated user to reach into the entire possible workspace.

The Phantom Premium 3.0 6DOF Haptic Device, as removed from the box, may be also be placed on a workbench by installing hard-rubber feet, provided in the accessory box directly to the securing metal bars. If desired the metal bars may be removed using the Hex Key provided and the feet installed directly on the Electronics Console. The device shown in figure 3-6 was placed on a Workbench with the Non-Skid Rubber Feet Installed.

FIGURE 5.



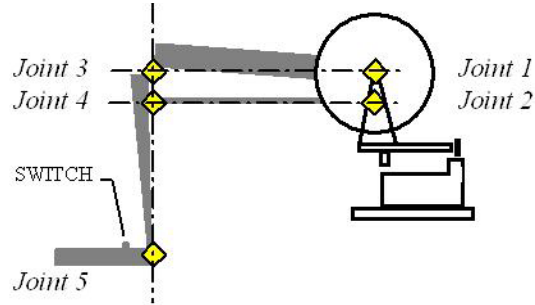
Neutral and Reset Positions

The Phantom Premium 3.0 6DOF sensors must be reset at the beginning of every program that uses the device. The position and orientation of the Phantom Premium 3.0 6DOF, when read from software, is always relative to the position in which the sensors were reset. The device can be reset in either the neutral or reset positions.

Neutral Position

The Phantom Premium 3.0 6DOF is in the neutral position when the lines joining the four joints in the four bar linkage system are at their right angle positions as shown in Figure 3-7. Specifically, the line joining Joints 1 and 3 as well as the line joining Joints 2 and 4 should be horizontal, and the line joining Joints 3, 4 and 5 should be vertical. When the device is in this position, the “shin” linkage would be slightly off vertical and the “thigh” linkage would appear to be cocked upward. If you have an encoder gimbal with stylus, the stylus should be positioned as indicated in the figure below with the switch on top.

FIGURE 6.



This is the default reset position that the Phantom Premium 3.0 6DOF should be in when starting up any of the demo programs that come with the system. This position also considered the (0,0,0) location for the device. If the Phantom Premium 3.0 6DOF is correctly reset, all software library functions assume that in this position the joint at the end of the handle is at the origin of its coordinate system.

Reset Position

The Phantom Premium 3.0 6DOF features a reset arm that can be used to reset the sensors in the same position. The reset arm swings forward and snaps into position under the head of the screw.

If you have an encoder gimbal with stylus, the stylus should be oriented to be inline with the shin, with the switch on top facing you. This will position the stylus pointing towards the floor as in **Figure 3-7** below. The encoder gimbal has labeling on it to identify which side should face the Phantom PREMIUM 3.0L Arm and which side should face the user.

FIGURE 7.



Your Phantom Premium 3.0 6DOF has been factory calibrated to its neutral position (0,0,0), and the corresponding reset position has been determined. This reset position is represented by three angles: ResetAngle0, ResetAngle1, and ResetAngle2, which are stored in the system registry (RegEdit).

These reset position values for your unit can be found on the calibration label located on the base of the Phantom Premium 3.0 6DOF Arm.

When finished resetting your Phantom Premium 3.0 6DOF, swing the reset arm out of the way. This reset position is not the neutral position. The Phantom Premium 3.0 6DOF should not be in this position when running the demonstration programs that come with it until the changes are made as described in this section.

If you wish to use this position as the reset position in your own software you will need to change the **<reset angles>** entry in the configuration file or you will not be able to accurately read the position and orientation of the Phantom Premium 3.0 6DOF.

1 USING THE PHANTOM PREMIUM DEVICE

Appendix: Troubleshooting

This section provides tips for correcting some common problems encountered with the Phantom Premium 3.0 6DOF device. If after following these steps, you cannot resolve the problem, please contact customer support (see Appendix B: "Customer Support").

#1 What do the lights on the amplifier box represent?

- **Power On:** Illuminates when the Amplifier Box power is ON. If not illuminated, check to see that:
 - The power switch on the back of the box is switched to the ON position.
 - The 110V power cord is plugged into an outlet.
 - The 110V power cord is plugged into the Amplifier Box.
- **Remote Switch:** The remote switch, also known as the kill switch, is the hand held switch or foot switch. This LED illuminates when the computer power is ON and the remote switch is in the ON position. The hand held switch is a "push-on"/ "push-off" switch whereas the foot switch is a momentary switch.
- **Software Enable:** Illuminates when the PC interface card has enabled the power amplifier. Axis 1, 2, 3: Illuminates when the respective Amplifiers are working.

#2 I received the following error message: "Error Code -0: I am receiving the error "Enable amps unsuccessful. Please make sure the remote switch is on. Driver Error: check that the Phantom device driver software is installed correctly. Error Value: 0."

For the Phantom Premium Line, check to see that the remote switch on the Amplifier Box is turned on.

Appendix: Customer Support

Warning DO NOT OPEN THE DEVICE. Attempting to open or repair the device by anyone other than a certified authorized service center voids the manufacturer warranty and hardware maintenance contract. There are no serviceable components in the Phantom Premium 3.0 6DOF device or power supply. You must return the device for servicing.

If you encounter any difficulties within your warranty period, you can obtain Technical Support through the three channels listed below. If you are out of warranty and do not have active maintenance, Technical Support is limited.

- If you purchased your Phantom Premium 3.0 6DOF device from a distributor, please contact them first.
- Customer Support can be reached via e-mail at SensibleSupport@geomagic.com.
- Customer Support can also be reached via telephone:
 - In the United States: 1-888-736-7225)
 - Outside the United States: +1-781-939-7444

Appendix: Regulatory Notices

FCC Notice (U.S. Only)

The Phantom Premium 3.0 6DOF® haptic device is classified by the Federal Communications Commission (FCC) as a Class B digital device.

Note: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Modifications not expressly approved by the manufacturer could void the user's authority to operate the equipment under FCC rules.

The following information is provided on the device covered in this document in compliance with FCC regulations:

Product Name: Phantom Premium 3.0 6DOF

Model Number: Model version of Premium 3.0 6DOF

Company Name: Geomagic, Inc.

NOTES

Any changes or modifications to the hardware not expressly approved by Geomagic could void the user's authority to operate this equipment.

This device is to be used with the supplied power supply only. Replacement power supplies are available directly from Geomagic.

Canadian Requirements:

Canadian Department of Communications Radio Interference Regulations

This digital apparatus, the Phantom Premium 3.0 6DOF haptic device, does not exceed the Class B limits for radio-noise emissions from digital apparatus as set out in the Radio Interference Regulations of the Canadian Department of Communications.

Règlement sur le brouillage radioélectrique du ministère des Communications

Cet appareil numérique, the Phantom Premium 3.0 6DOF haptic device,

respecte les limites de bruits radioélectriques visant les appareils numériques de classe B prescrites dans le Règlement sur le brouillage radioélectrique du ministère des Communications du Canada.

European Requirements:

EN 55022 Statement

This is to certify that the Geomagic Phantom Premium 3.0 6DOF haptic device is shielded against the generation of radio interference in accordance with the application of Council Directive 89/336/EEC, Article 4a. Conformity is declared by the application of EN 55022 Class B (CISPR 22).

Warning: This is a Class B product. In a domestic environment, this product may cause radio interference, in which case, the user may be required to take appropriate measures.

Achtung: Dieses ist ein Gerät der Funkstörgrenzwertklasse B. In Wohnbereichen können bei Betrieb dieses Gerätes Rundfunkstörungen auftreten, in welchen Fällen der Benutzer für entsprechende Gegenmaßnahmen verantwortlich ist.

Attention: Ceci est un produit de Classe B. Dans un environnement domestique, ce produit risque de créer des interférences radioélectriques, il appartiendra alors à l'utilisateur de prendre les mesures spécifiques appropriées.

Appendix: Working with Pinch End Effectors

The Phantom family of haptic devices enables attaching interchangeable end effectors that provide pinch functionality. There are two pinch-capable grips: thumb-pad and scissors

Requirements

- A Pinch-capable Phantom Premium device (3.06DOF).
- Latest version of the Phantom Device Driver (PDD).
- OpenHaptics v3.0.

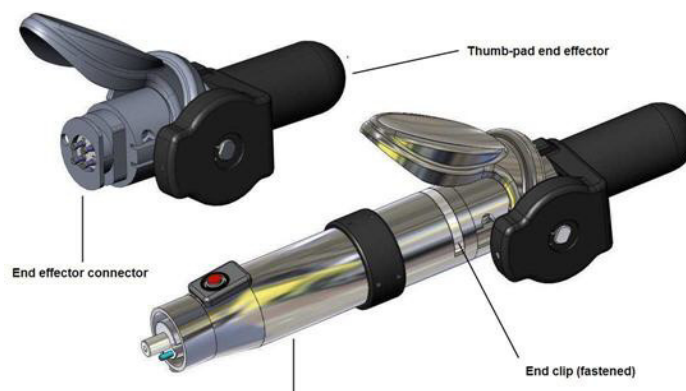
Specifications

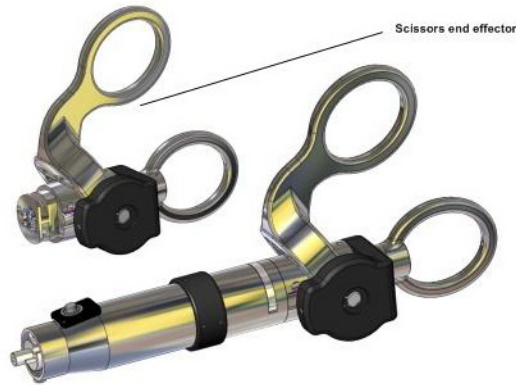
- Range of Motion: 0 to 45 degrees
- Encoder Resolution: <0.1 degrees
- Force Feedback: None

Installing the End Effector

- 1 Remove the end cap by opening the end clip and carefully sliding out the cap.
- 2 Align the male connector of the end effector with the female end of the handle and push to insert it. Make sure that the vertical edge of the end effector connector aligns with the vertical edge of the 6 DOF handle connector.
- 3 Close the end clip tightly to keep the end effector in place.

The diagrams below show the thumb-pad and scissors attachments before and after assembly.





Removing the End Effectors

- 1 Open the end clip.
- 2 Carefully disconnect the end effector from the 6 DOF handle. Make sure to apply the end cap to the 6 DOF handle whenever an end effector is not connected.

Calibrating the End Effectors

After you have installed the Phantom Device Driver (PDD) and have connected the Phantom device to your computer, you will need to calibrate the device and the thumb-pad or scissors end effectors. End effectors are calibrated through the Read encoders tab of the Phantom Test dialog.

- 1 From **Start>All Programs>Sensable**, open **Phantom Test**.
- 2 Hold the Phantom device in the neutral position (with the 4 rotary joints lined up) and press the Space bar on the keyboard.
- 3 The Pinch option in the dialog will report a status of Uncalibrated.
- 4 Close (press) the end effector completely, and press the Space bar on the keyboard.
- 5 Open (release) the end effector completely, and the press the Space bar again.
- 6 The Pinch option in the dialog should now show continuous readings from the end effector encoder (as shown). This indicates that the end effector is calibrated and ready to use.

Note When the thumb-pad end effector is completely open (released), the Pinch reading corresponds to zero. (If using scissors, it corresponds to one.) When the thumb-pad end effector is completely closed (pressed completely), the Pinch reading corresponds to one in normalized encoder values. (If using scissors, it corresponds to zero.) The intermediate positions are distributed between zero and one (or vice versa, if using scissors).

Appendix: Device Specifications

	Premium 3.06DOF
Workspace	Translational= 33 W x 23 H x 16 D inches 838 W x 584 H x 406 D mm Rotational= Yaw: 297 degrees/5.18 radians, Pitch: 260 degrees/4.54 radians, Roll: 335 degrees/5.85 radians
Footprint	Detachable Portion= 8 W x 8 D inches 203 W x 203 D mm Electronics Console (Amp box)= 15 W x 20 D inches 381 W x 508 D mm
Range of Motion	Full arm movement pivoting at shoulder
Nominal Position Resolution	>1000 dpi ~0.02 mm
Backdrive friction	0.75 oz 0.2 N
Maximum exertable force (nominal position)	Translational=4.9 lbf 22 N Rotational= Yaw & Pitch: 27 oz-in/188 mNm, Roll: 7oz-in/48 mNm
Continuous exertable force (nominal position)	Translational= 0.7 lbf 3 N Rotational= Yaw & Pitch: 27oz-in/188mNm, Roll: 7oz-in/48 mNm
Stiffness	5.7 lbf in ⁻¹ 1 N mm ⁻¹
Inertia (apparent mass at tip) - without encoder gimbal	< 0.35 lbm < 159 g
Force Feedback	x, y, z, Tx, Ty, Tz
Position Sensing	x, y, z, roll, pitch, yaw
Interface	Parallel Port
Supported Platforms	PC
OpenHaptics™ Toolkit Compatability	Yes

