

HapticMASTER Installation and User Manual



RESTRICTED RIGHTS

Use, duplication or disclosure by the Government is subject to restriction as set forth in subparagraph (c) (1) (ii) of the Rights in Technical Data and Computer Software Clause of DFARS 52.227-7013. (1

Moog Inc.

East Aurora, NV 14052

Information in this document is subject to change without notice and does not represent a commitment on the part of MOOG B.V. The Software described in this document is furnished under the Software License Agreement. The Software may be used or copied only in accordance with the terms of the license. No part of this document may be reproduced, stored in a retrieval system, or transmitted in any form or by any means electronic or mechanical, including photocopying and recording, for any purpose, without the express written permission of MOOG B.V.

All rights reserved. Disclosure to third parties of this document or any part thereof, or the use of any information contained therein for purposes other than provided for this document, is not permitted, except with prior and express written permission.

Copyright © 2012 by MOOG B.V., All Rights Reserved.

MOOG B.V.	Visit/shipping address	Phone	+31 (252) 462 065
P.O. Box 187	Pesetaweg 53	fax	+31 (252) 462 001
2150 AD Nieuw-Vennep	2153 PJ Nieuw-Vennep	email	robotics@moog.com
The Netherlands.	The Netherlands.		http://www.moog.com

Microsoft is a registered trademark and Windows, Window Explorer are trademarks of Microsoft Corporation.

All other brand and product names are the property of their respective owners.

Document Version

Original version	English
Other languages available	---

Revision record

Iss.	Description	Compiled by	Date
4.0	Converted to MOOG template. Mounting of arm updated	JM	21 December 2006
4.1	Drawing of bottom plate and force sensor added	JM	27 February 2007
4.2	Section added for changing the ip address of the host pc from floating to fixed	JM	11 March 2008
4.3	Reboot sequence added (first pc/network, than HM)	JM	28 March 2008
4.4	Converted to new MOOG template. Section for customized End Effectors added	JM	27 February 2009
5.0	Changed document to fit a new HapticMASTER, with HapticAPI2 and Web Interface instead of FCS Explorer	EH	10 December 2010
5.1	Install CD changed in Software CD	EH	12 January 2012

Summary

This document describes how to install the HapticMASTER: how the machine should be assembled, how the cables should be connected, what the basic software settings are. It also describes the basic operation procedures.

Contents

1.	Safety	6
1.1	Safety precautions before using the HM	6
1.1.1	Placement of the HM	6
1.1.2	Position of the human operator	7
1.1.3	Placing the emergency button	7
1.1.4	Mind the cables	7
2.	Requirements set-up	8
2.1	Host PC system requirements	8
2.2	Network requirements	8
2.3	Power requirements	8
3.	Placing and assembling the HapticMASTER	9
3.1	System overview	9
3.2	Moving and handling the HapticMASTER	9
3.3	Placing the HapticMASTER robot	10
3.4	Placing the HapticMASTER electronics box	10
3.5	Placing the emergency switch	10
3.6	Mounting the robot arm to the robot base	10
3.7	Mounting the force sensor and the standard end effector	11
3.8	Mounting additional end effectors	12
4.	Connecting the HapticMASTER	13
4.1	Interconnecting the robot and the control box	13
4.2	Connecting the emergency circuit	13
4.3	Providing electrical power	13
4.4	Connecting the system to a network	14
4.4.1	Setting the host PC to a fixed IP Address.	14
4.4.2	Resetting the host PC to a floating IP address.	16
5.	Software CD	18
6.	Web Interface	19
6.1	About the Web Interface	19
6.2	Opening a Web interface session	21
6.3	Changing the HapticMASTER's IP Address	22
6.4	Rebooting the device	24
6.5	Initializing & changing states	25
6.6	Changing the Virtual Mass	26
7.	Operating the HM	27
7.1	Maximum end effector forces	27
7.2	Maximum robot forces	27
7.3	Holding the end effector	27
7.4	End effector contact with the environment	28

7.5	Using the emergency button	28
7.6	Customized end effectors	28
8.	First use of the HapticMASTER.....	30
Appendix A.	Dimensions.....	31
A.1	Bottom plate	31
A.2	Mounting holes on force sensor	31

1. Safety

The HapticMASTER is a powerful robot that can generate high forces and high velocities. Therefore, it should be handled with care and responsibility. By respecting the procedures in this manual, a safe operation (for both the robot and the human) will be achieved. Please read the ENTIRE manual before switching on the HapticMASTER for the first time.



The HapticMASTER is a robotic device that contains electronic components, sensors and actuators. Like all mechatronic systems, the HapticMASTER depends on the delicately tuned balance between the components. This implies that if any of the components fail, the system cannot operate properly, thus cannot be considered as safe. If a failure of one of the components is detected, please contact your vendor immediately.

1.1 Safety precautions before using the HM

Before you start using the HapticMASTER, please bear in mind the following safety precautions and verify them each time you activate the HapticMASTER!

1.1.1 Placement of the HM

The HapticMASTER is designed to move according to the commanded signals of the virtual environment and the measured signal at the end effector. This implies that the HapticMASTER will neglect physical contact with any part of the robot other than the force sensor and end effector. The area at the back end of the robot arm is therefore potentially dangerous and should be avoided as long as the HapticMASTER is powered. Keep this area clear from both objects and individuals during operation (see Figure 1-1). Keep in mind that the workspace is spatial, thus also has a vertical excursion!

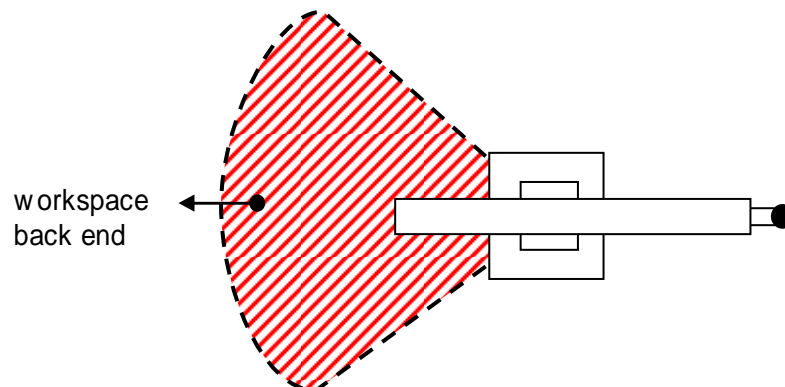


Figure 1-1 workspace back end HapticMASTER



Keep the area at the back of the robot arm clear from objects!!!

1.1.2 Position of the human operator

Similar to the back end workspace as previously described, the front end workspace of the HapticMASTER robot arm also has a large insensitive part. This is the part other than the force sensor and EndEffector, which does not react on physical contact. Again, keep this area free from objects during operation. Because the HapticMASTER is operated with the EndEffector at the front side, it is therefore strongly advised to place the operator right outside the EndEffector workspace (see Figure 1-2). Indicate the safe operator area to avoid human errors.

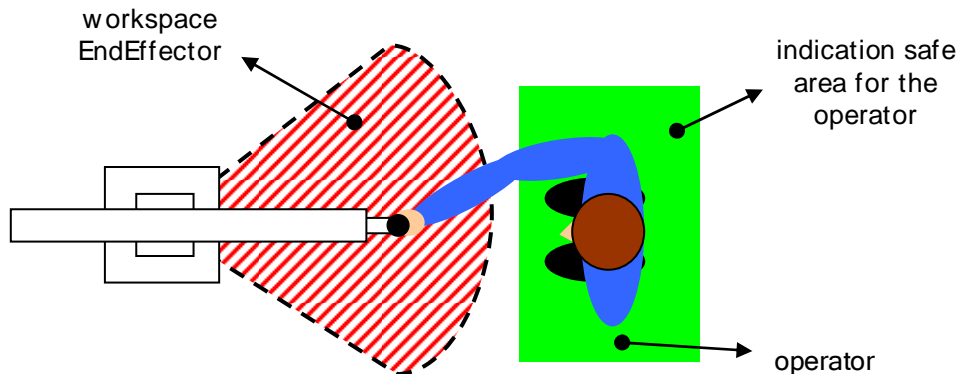


Figure 1-2 workspace EndEffector



Place the operator outside the EndEffector workspace!!!

1.1.3 Placing the emergency button

The emergency button will disable the HapticMASTER. Therefore keep this button within reach and vision of the operator.



Place the emergency button within operator vision and reach!!!

1.1.4 Mind the cables

The electronics box and the robot arm are connected to each other by means of connecting cables. Keep in mind that persons could step on the connectors, or trip over the cables. Thus, when placing the HapticMASTER, try to minimize the chance of these events to occur.

If a connecting cable other than the network cable gets disconnected during operation, please turn off the HapticMASTER before connecting the cables again! A software guard will detect loss of sensor signals and prevent sudden movements of the robot arm.

2. Requirements set-up

2.1 Host PC system requirements

The HapticMASTER system has its own haptic controller, which can be commanded from the user's computer. From now on the user's computer is referred to as the "host" computer.

The only requirement on the "host" computer is that it has a 100 Mbps Ethernet card, and the capability to run the very simple software API needed to connect to the HapticMASTER controller via this Ethernet line. The API is available for WIN32, LINUX and MAC.

There are no haptic rendering performance requirements of the host computer. The haptic rendering takes place in the on-board computer of the HapticMASTER. Visual or auditory rendering must be performed by the user, e.g. via the host computer. The API also allows the "host" computer to participate in the haptic rendering process if so desired. In that case, part of the processing load will be on the host computer too.

2.2 Network requirements

There are no performance requirements on the network connection, unless the user has decided to do part of the haptic rendering on the "host" computer. Each call required for data transfer between host computer and HapticMASTER requires approximately 0.6 [ms].

In general the haptic rendering will be performed on the haptic controller of the HapticMASTER. Then the network connection will only govern the performance of synchronization between visual and haptic rendering, and the performance of remote master-slave functionality if applicable.

2.3 Power requirements

The HapticMASTER system can be powered from any normal wall socket.

The input voltage range is from 90 to 264 VAC, frequency from 50-60 Hz. This implies that it works both on the 220 Volt standard, as on the 110 Volt standard. The power consumption will not exceed 500W.

3. Placing and assembling the HapticMASTER

3.1 System overview

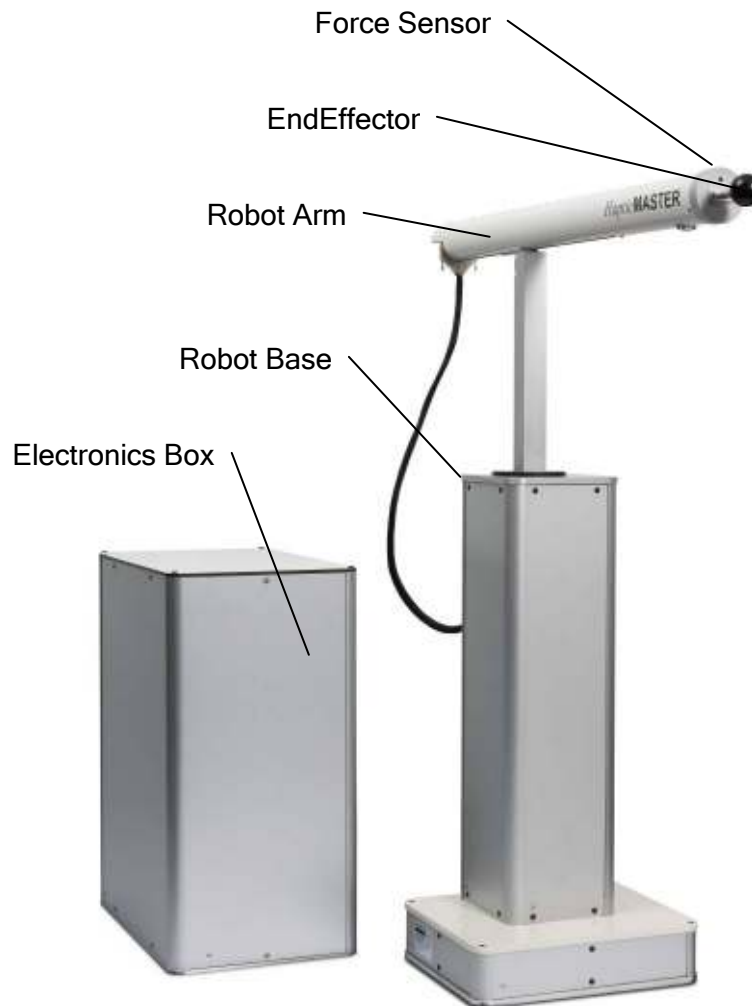


Figure 3-1 System overview

3.2 Moving and handling the HapticMASTER

The HapticMASTER and electronics box are delicate equipment. Handle them carefully, without dropping or toppling.

Unpowered, the arm of the robot is mechanically back drivable in all directions between its end stops. If done carefully, moving the robot arm about is not a problem.



Do not move or lift the unpowered robot arm by its end effector! This may damage the force sensor.

When lifting the robot by its arm, be prepared that the arm may lift and sway. It is best to lift the robot by supporting the robot base.

3.3 Placing the HapticMASTER robot

Place the robot with enough space around it for free movement (see Figure 3-1). Move the unpowered robot arm by hand to verify that it will not strike walls or objects, especially at the rear. Carefully move the arm completely “in” to the rear and sideways to both sides, to check ample freedom of movement.

Avoid the possibility of people standing behind or to the side of the machine, e.g. by placing fences or steps on the floor.

If desired, fix the base of the robot to the floor or a frame. This is not necessary for normal operation, or for running the demo software. Be aware that fixing the robot to the floor eliminates the safety mechanism of toppling when large forces are exerted! For a drawing of the mounting holes in the bottom of the HapticMASTER see appendix A.1.

3.4 Placing the HapticMASTER electronics box

Place the electronics box in a convenient location, not too far from the robot. Handle the box with the care normally required for typical electronics equipment such as PC's. If necessary, the box is strong enough to carry static objects of reasonable weights.

The on-off switch of the machine is located at the back of the electronics box, near the connector sockets. Keep the switch easily accessible without having to enter the work area of the robot. Keep enough space for the connectors and their cables, without undue bending.

Make sure the ventilation holes of the electronics box are not unduly obstructed.

3.5 Placing the emergency switch

Place the emergency switch in an accessible location, near the supervisor's workstation, and outside the work area of the robot, or integrate the emergency switch into your own console or safety system.

Avoid placing the emergency switch on the floor, since it tends to get stepped on inadvertently in that position.

3.6 Mounting the robot arm to the robot base

Place the arm by inserting its mounting block into the vertical square tube coming out of the robot base. There are 2 fixing bolt mounted in the mounting block. Do not remove the fixing bolts.

Through the two holes in the tube, tighten the two fixing bolts with the supplied Allen key nr.2.5.



Figure 3-2 Mounting the robot arm



Figure 3-3 Allen key 2.5 in the bolt

Connect the male 37-pin sub-D connector and the male 15-pin sub-D connector coming from the upper part of the robot base to the corresponding female connectors at the back end of the robot arm. Secure the connectors by tightening the hold-down bolts at both sides (use the supplied screwdriver if necessary).

3.7 Mounting the force sensor and the standard end effector

Connect the force sensor to the sub-D connector coming from the front end of the HapticMASTER robot arm.

Gently insert the force sensor into the arm. Make sure to mount the force sensor with the sticker saying "TOP" on the topside.



Figure 3-4 Mounting the force sensor

Fix the force sensor by tightening the four screws with the supplied Allen key nr. 2.5 (Figure 3-4).

Mount the standard end effector to the front side of the force sensor by tightening the two screws on each side with the supplied Allen key 2.5.

3.8 Mounting additional end effectors

Besides the standard end effector, there are 4 additional gimbals available from MOOG:

- Passive tool gimbal (part. no.: RHG04141)
- Passive grip gimbal (part. no. RHG04283)
- Passive ring gimbal (part. no.: RHG03001-301)
- Active ring gimbal (part. no.: RHG03001-302)

Also customized end effectors can be used. See section 7.6 for guidelines in using customized end effectors



Make sure the HapticMASTER is switched off before changing any gimbals!

- Remove the standard end effector by unscrewing the two screws with the supplied Allen key nr. 2.5.
- Mount the end effector to the force sensor by tightening the two screws on each side of the gimbal with the supplied Allen key nr. 2.5.
- Connect the male 3-row 15-pin sub-D connector coming from the gimbal to the corresponding female connector located on the bottom of the HapticMASTER arm. Secure the connector by tightening the hold-down bolt (use the supplied screwdriver if necessary).
- For the active ring gimbal, connect the male 2-row 15-pin sub-D connector coming from the gimbal to the corresponding female connector located on the top side of the HapticMASTER arm. Secure the connector by tightening the hold-down bolt (use the supplied screwdriver if necessary).
- Connect the multi-pole connector coming from the gimbal to the corresponding female connector located on the HapticMASTER arm. Secure the connector by inserting it until it clicks (to disconnect, pull back the locking sleeve of the connector).



When using end effectors, increase the virtual mass of the HapticMASTER by the weight of the end effector.

4. Connecting the HapticMASTER

4.1 Interconnecting the robot and the control box

First, connect the robot to the electronics box with the 33-pin sub-D connector signal cable (see Figure 4-1). It has a male connector at one end and a female connector at the other end. It can be connected in only one way. Secure the connectors by tightening the hold-down bolts at both sides (if necessary, use the supplied screwdriver).



Figure 4-1 33-pin SUB-D Connector



Figure 4-2 Mixed SUB-D connector

With the signal cables securely mounted, connect the low voltage power cable. This is the cable with the flat 24-pin mixed SUB-D connectors (see Figure 4-2). This cable also has a male connector at one end, and a female connector at the other end. It can only be connected in one way. Secure the connectors by tightening the screws on each side of the connector with the supplied screwdriver.

4.2 Connecting the emergency circuit

By default, the emergency switch that comes separate from the system cuts the mains electrical power to the system when pressed. Put the connector of the emergency switch in the appropriate connector at the back of the electronics box. Without the emergency switch, the robot will not work.

4.3 Providing electrical power

The electronics box has a standard main power cable. Plug the cable into a normal wall outlet. Power consumption is similar to that of a few office PCs.

4.4 Connecting the system to a network

Communication to the device is via 100 Mbps Ethernet. The specifications are:

Table 4.1 Ethernet specifications

speed	100 [Mbps]
protocol	TCP / IP
default IP address	10.30.203.x where x is the system number, equal to the serial number of the machine, indicated on the machine specific FCS sticker on the system.

The “host”, i.e. user PC must be equipped with a 100 Mbps Ethernet card. There are three basic ways of coupling the device to the host PC :

- Direct connection using a zero-modem Ethernet cable (cross cable).
- Connection with normal Ethernet cables via an intermediate “hub”.
- Connection with normal Ethernet cables via a local (office) network.

In the first case, the IP address of the HapticMASTER must be in the range of the IP address of the host computer (see section below).

In the two other cases, the IP address of the HapticMASTER must be in the range of the local network to which the host computer is connected.

To change the IP address of the HapticMASTER, please check section 6 - Web Interface.



When using a direct connection (cross cable) between a pc and a HapticMASTER, make sure the pc is booted before switching on the HapticMASTER



If the Ethernet connection (either direct or network) is disconnected and re-connected, the HapticMASTER must be rebooted.

4.4.1 Setting the host PC to a fixed IP Address.

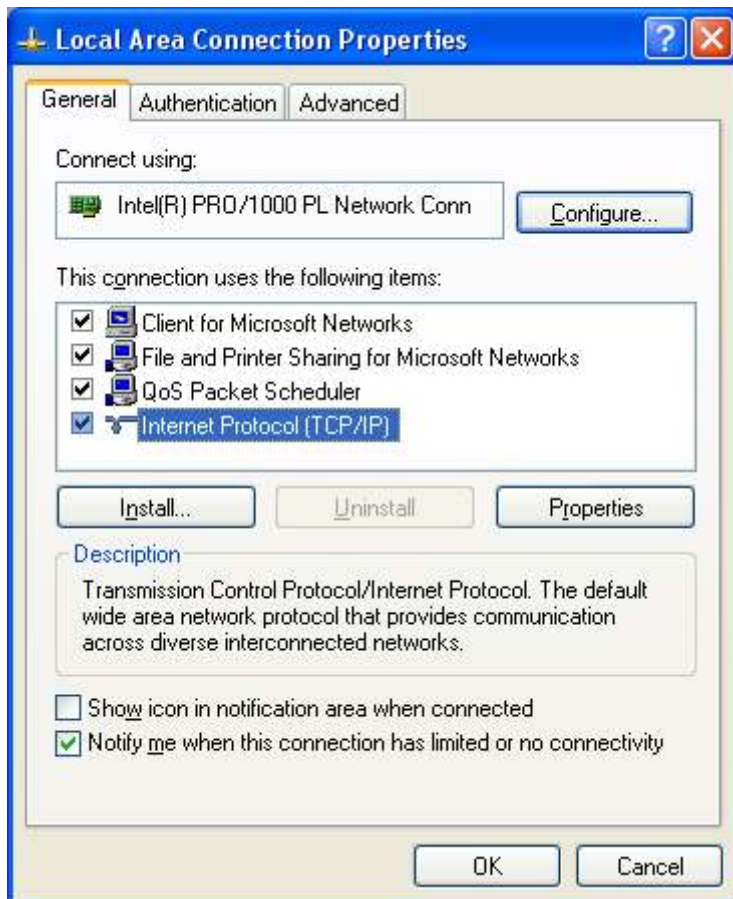
In the start menu select: “Settings” → “Network Connections” → “Local Area Connection”



In the Local Area Connection Status window, select “Properties”



In the Local Area Connection Properties window, select “Internet Protocol (TCP/IP)”



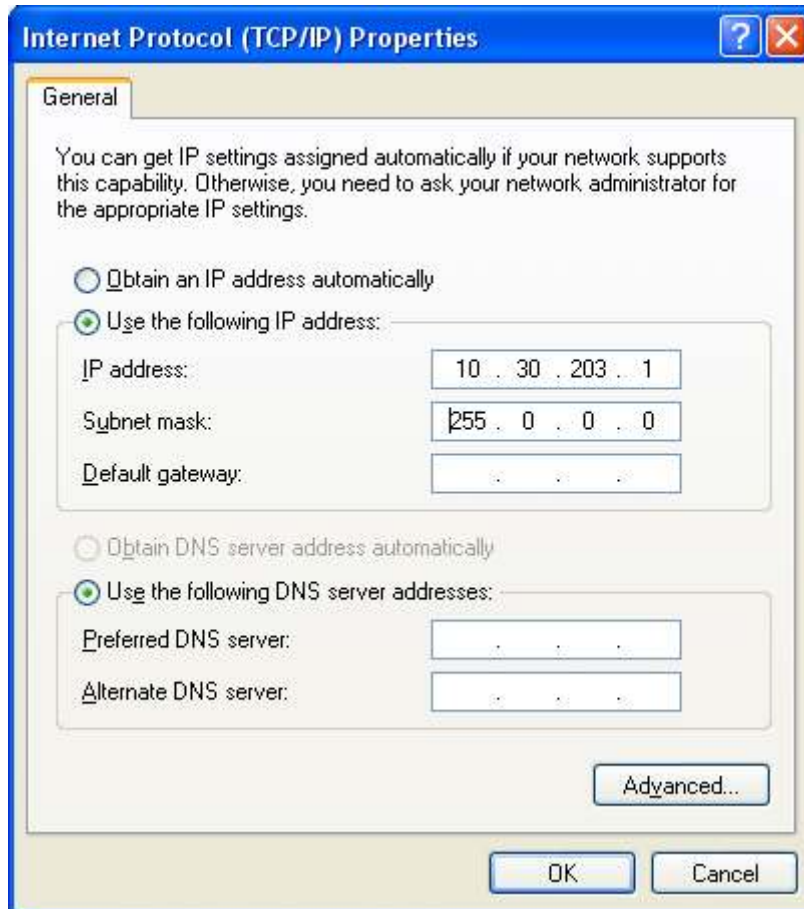
In the Internet Protocol (TCP/IP) Properties select “Use the following IP address”

For the IP address, type an address which differs from your HapticMASTER IP Address only by the last number.

E.g. if the HapticMASTER has 10.30.203.35 then you can use 10.30.203.1.

Set the subnet mask 255.0.0.0

The DNS server addresses are filled in automatically.



Press "ok" to apply the changes. The Internet Protocol (TCP/IP) Properties window closes.

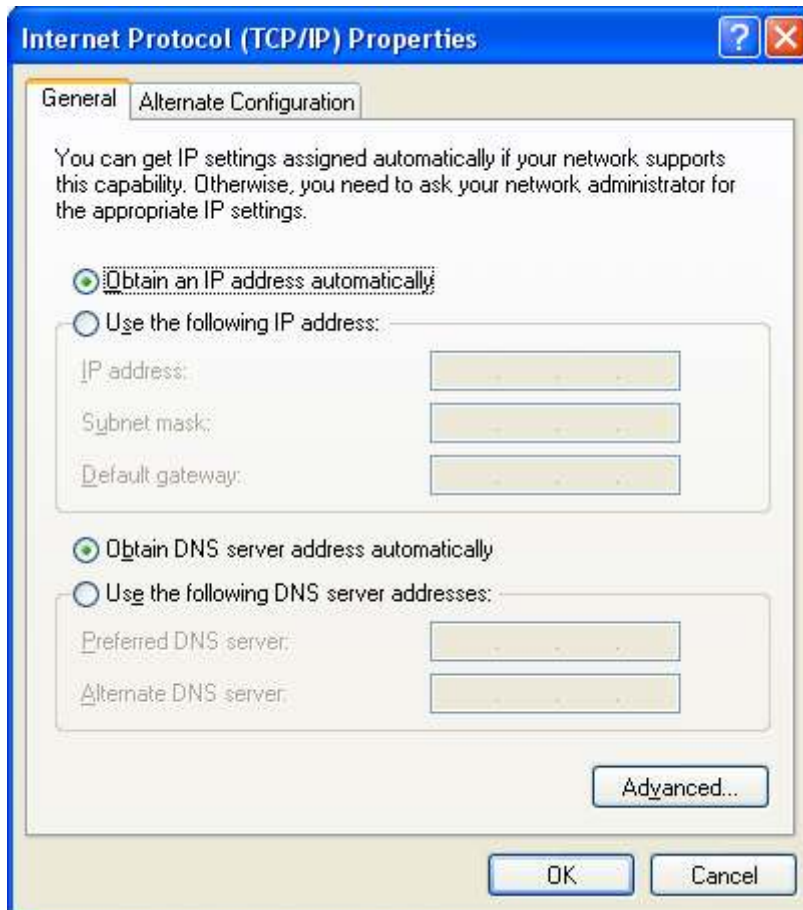
Press "ok" to apply the changes. The Local Area Connection Properties window closes.

Close the Local Area Connection Status window.

4.4.2 Resetting the host PC to a floating IP address.

If you had to change the ip address of your pc from a floating IP address to a fixed IP address in order to connect to the HapticMASTER, follow the steps below to undo the changes and restore your pc to a floating IP address.

Follow the steps in the previous section to open the Internet Protocol (TCP/IP) Properties window. In that window, select "Obtain an IP address automatically" and "Obtain DNS server address automatically".



Press "ok" to apply the changes. The Internet Protocol (TCP/IP) Properties window closes.

Press "ok" to apply the changes. The Local Area Connection Properties window closes.

Close the Local Area Connection Status window.

5. Software CD

Insert the accompanied CD in your CD-ROM drive. You can copy the contents to your local hard disk.

The CD includes the following components:

- Demos
- Programming Examples
- HapticAPI2
- HapticMASTER utility library
- OpenGL toolkit glut32.dll, if not installed already
- Documentation

6. Web Interface

6.1 About the Web Interface

The Web Interface can be used to communicate with the HapticMASTER without the need to write and/or compile any software code. With the Web Interface you can initialize the HapticMASTER, change its states, reboot it, create haptic effects and objects and query many of the Real-Time variables available within the HapticMASTER itself.

The Web Interface's layout is divided into a left panel and a right panel.

The left panel functions as a menu, and the right panel reacts upon a selection in the left panel by providing the input and output fields that belong to that menu selection.

Menu Panel

- Configuration Log
- HapticMASTER
- Force Sensor X
- Force Sensor Y
- Force Sensor Z
- PVA Limiter R
- PVA Limiter Phi
- PVA Limiter Z
- Joint Controller R
- Joint Controller Phi
- Joint Controller Z
- Encoder R
- Encoder Phi
- Encoder Z
- Amplifier R
- Amplifier Phi
- Amplifier Z
- HapticRenderer

HapticMASTER

State	Cartesian	Joint	MeasForce	Workspace	Sync	Version	Polynomials
virtual mass							
Inertia							
X axis [m]							
Model position X	0.0258387						
Meas position X	0.0258279						
Model velocity X	7.01837e-74						
Meas velocity X	0						
Model input force X	0.0221482						
Y axis [m]							
Model position Y	0.203088						
Meas position Y	0.203083						
Model velocity Y	1.0025e-75						
Meas velocity Y	0						
Model input force Y	0.0345583						
Z axis [m]							
Model position Z	-0.0166471						
Meas position Z	-0.0166408						
Model velocity Z	-1.43229e-74						
Meas velocity Z	0						
Model input force Z	0.0035						

Data Input/Output Panel

Input field

Output fields

Units

Variable names

Apply input changes

Above is a sample Web Interface page. The *HapticMASTER* option was clicked on the Menu Panel on the left side. Consequently, the *Cartesian* tab was chosen from the Data Input/Output panel on the right side. On the Data input/output panel four columns are visible:

- Description (variable names)
- Curr. value (output fields reflecting the current value of the specified variable)
- New value (input fields for new value inputs - in the example only one field)
- Unit (the units in which the value is specified)

In the *New value* column, push buttons can be visible when the input field should trigger an action instead of changing the value of a variable.

When a value was entered in an input field, one should click on the **apply** button in order to copy the edited values into the real-time system.

The **refresh** button refreshes the output fields with up-to-date values.

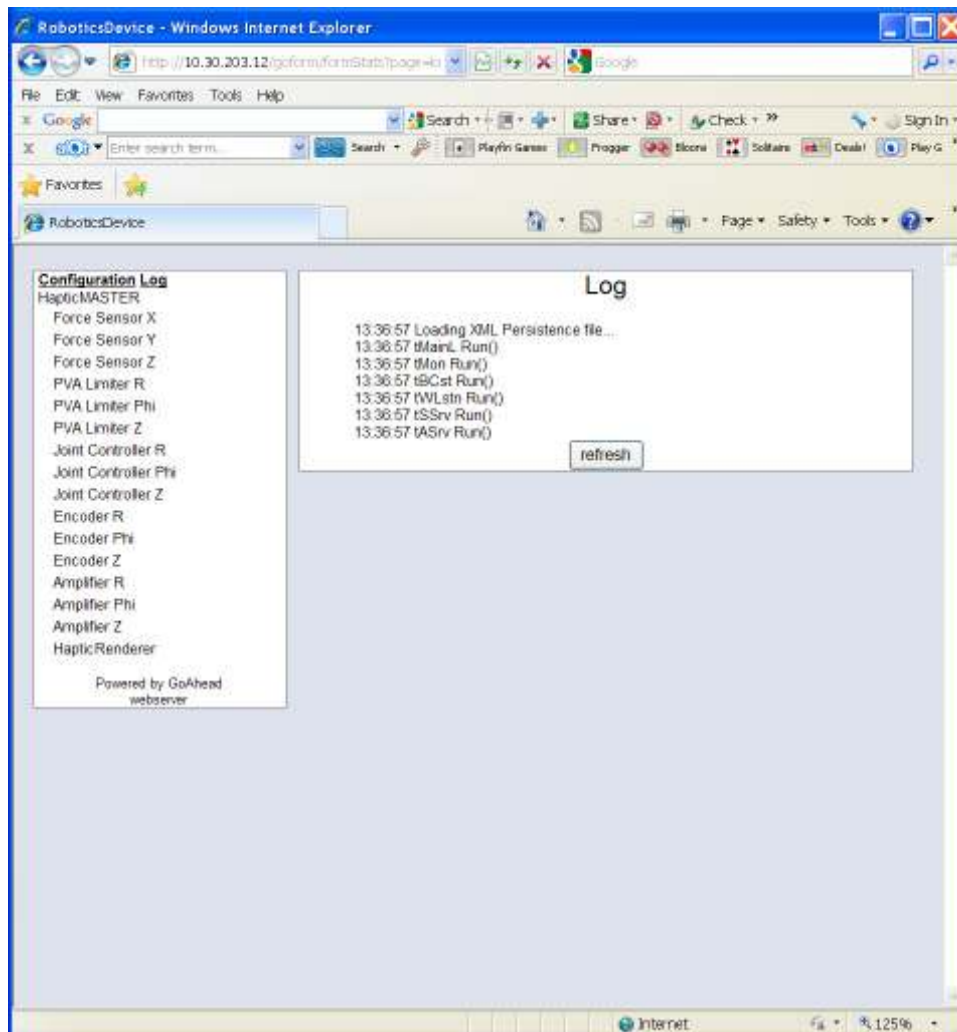
In the next sub sections we describe some commonly used functions of the Web Interface. For more information about the capabilities of the Web Interface, please refer to the document "*HapticMASTER Web Interface*", which serves as a reference manual for the Web Interface's features.

6.2 Opening a Web interface session

About 40 seconds after turning on the HapticMASTER device, its Web Interface will be available.

You simply need to open a web browser (E.G. Internet Explorer or Firefox) and type the HapticMASTER's IP address in the address bar.

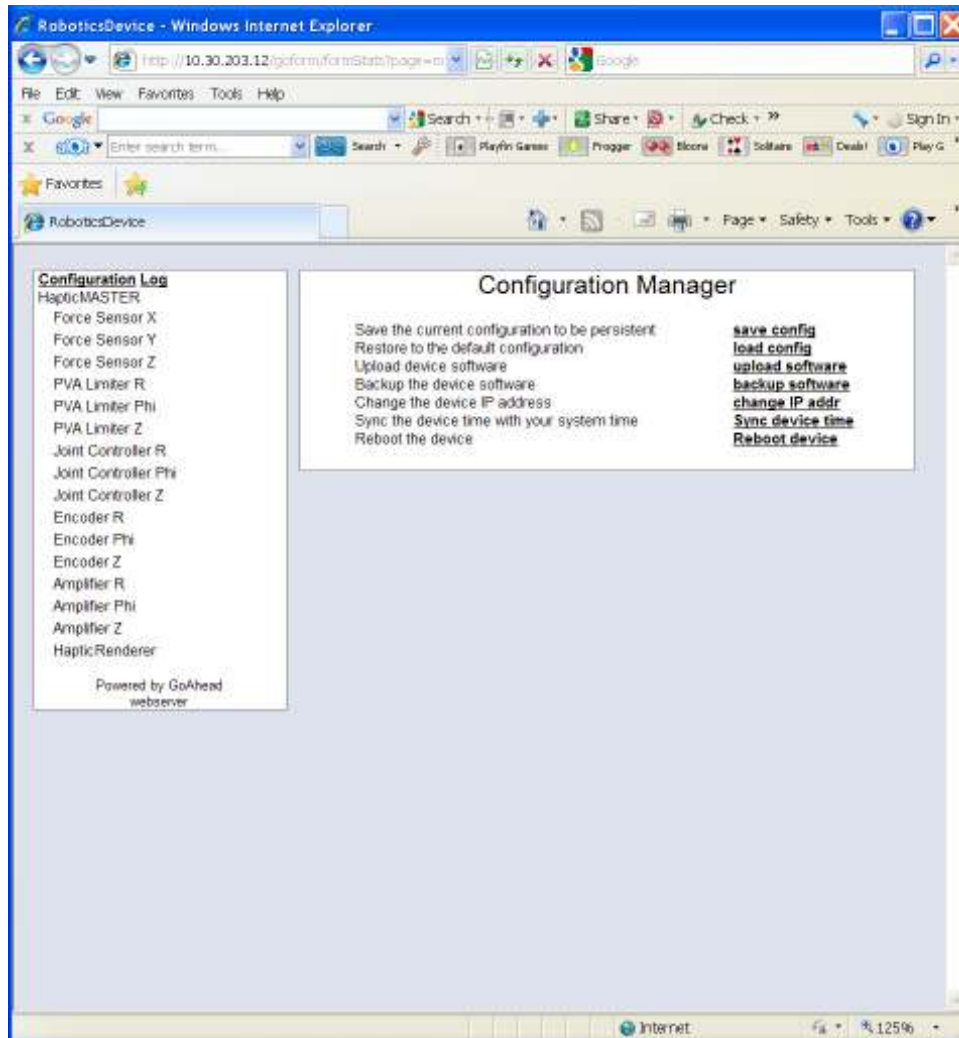
E.G.: If the HapticMASTER's IP Address is 10.30.203.12, you type <http://10.30.203.12> in the address bar. You will then see the *Log* window of the Web Interface:



In the *Log* window, informative message and error messages from the HapticMASTER are logged. Error messages are displayed in **RED**. If things go wrong with the HapticMASTER, please enter this page to see whether any error messages appear.

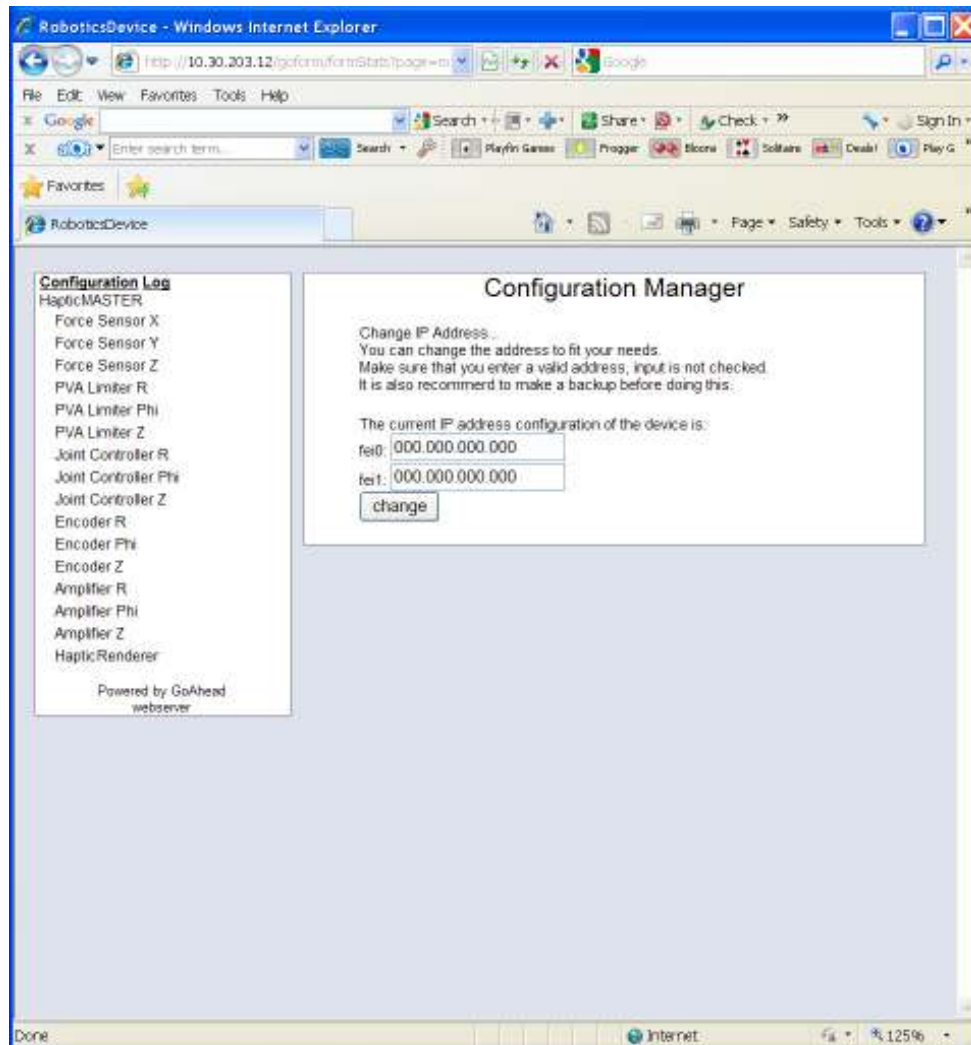
6.3 Changing the HapticMASTER's IP Address

To change the HapticMASTER's IP address, first click on the *Configuration* menu option. The following screen appears:



Now click on the *change IP addr* link on the panel on the right side.

The following screen opens:



Change the *fe0* field to the desired IP address.

Ignore the *fe1* field (it is used for devices with multiple network cards).

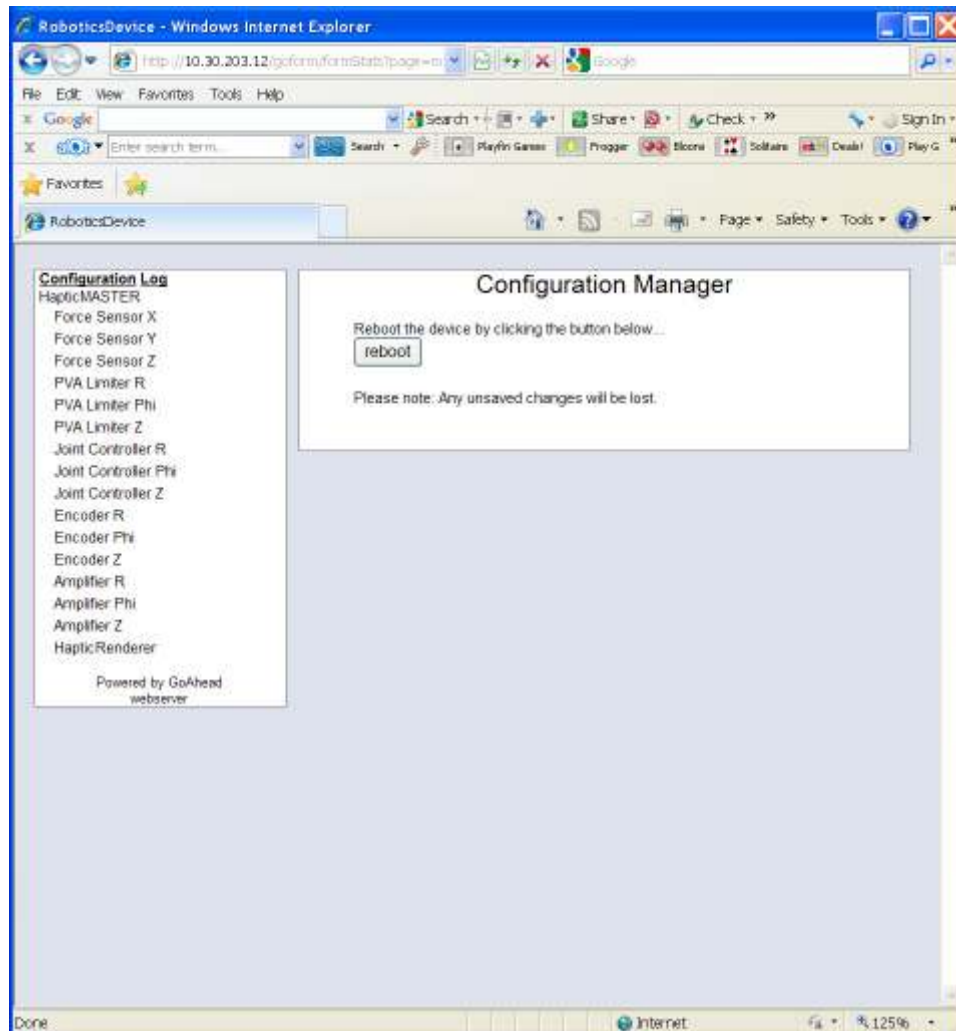
When finished entering the new IP address, click the **change** button to accept the values.

After changing the IP address, you need to reboot the HapticMASTER (see next section).

In the web browser you now need to enter the new IP address in the *address* tab.

6.4 Rebooting the device

To reboot the device, choose the *Configuration* menu option. Then click on the *Reboot device* link on the panel on the right side. The following screen appears:



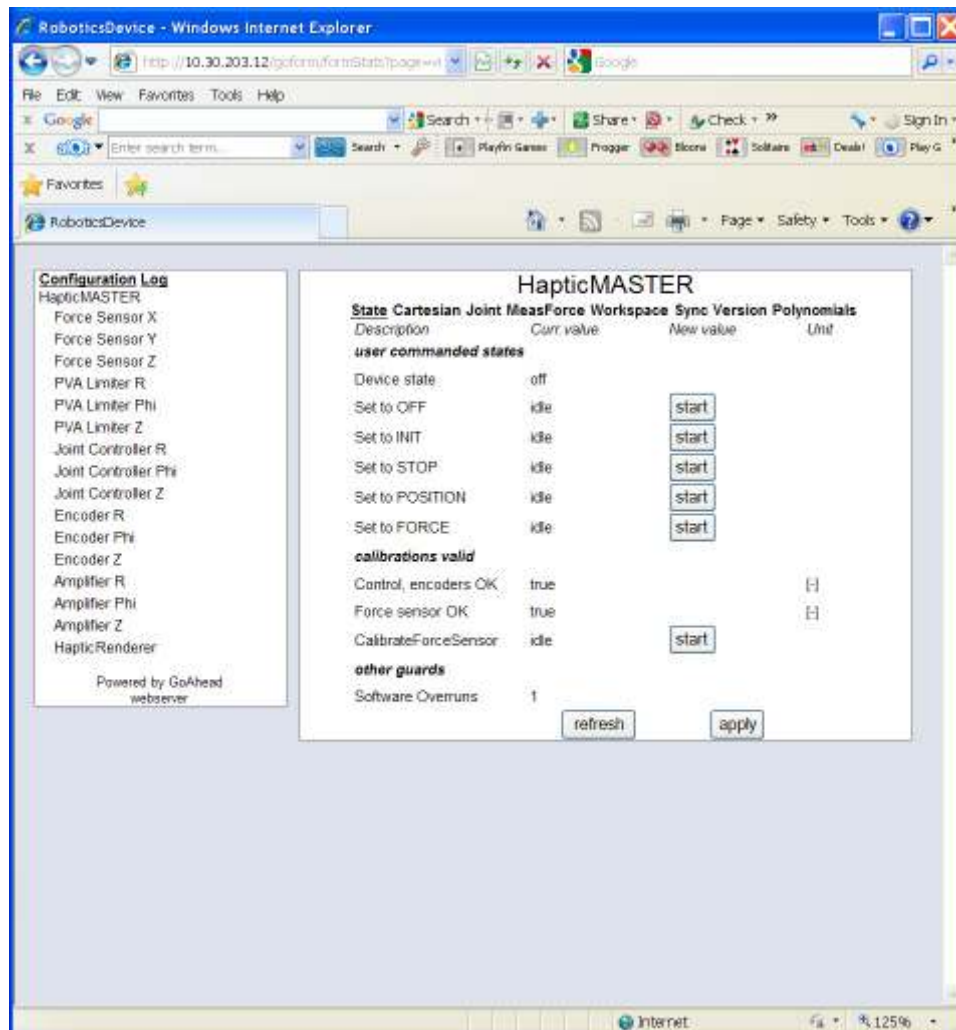
Clicking the **reboot** button reboots the HapticMASTER. Please wait for about 40 seconds before you reload the Web Interface in your web browser. The HapticMASTER needs the time to reboot and make the Web Interface available again.

6.5 Initializing & changing states

The Web Interface can be easily used to identify the current state of the HapticMASTER and to change its current state.

When the HapticMASTER is just turned on, the end stops of all 3 axes (R, Phi and Z) are not known yet. The HapticMASTER still needs to initialize. This is done by choosing the *HapticMASTER* option from the menu on the left.

The *state* tab of the *HapticMASTER* menu appears:



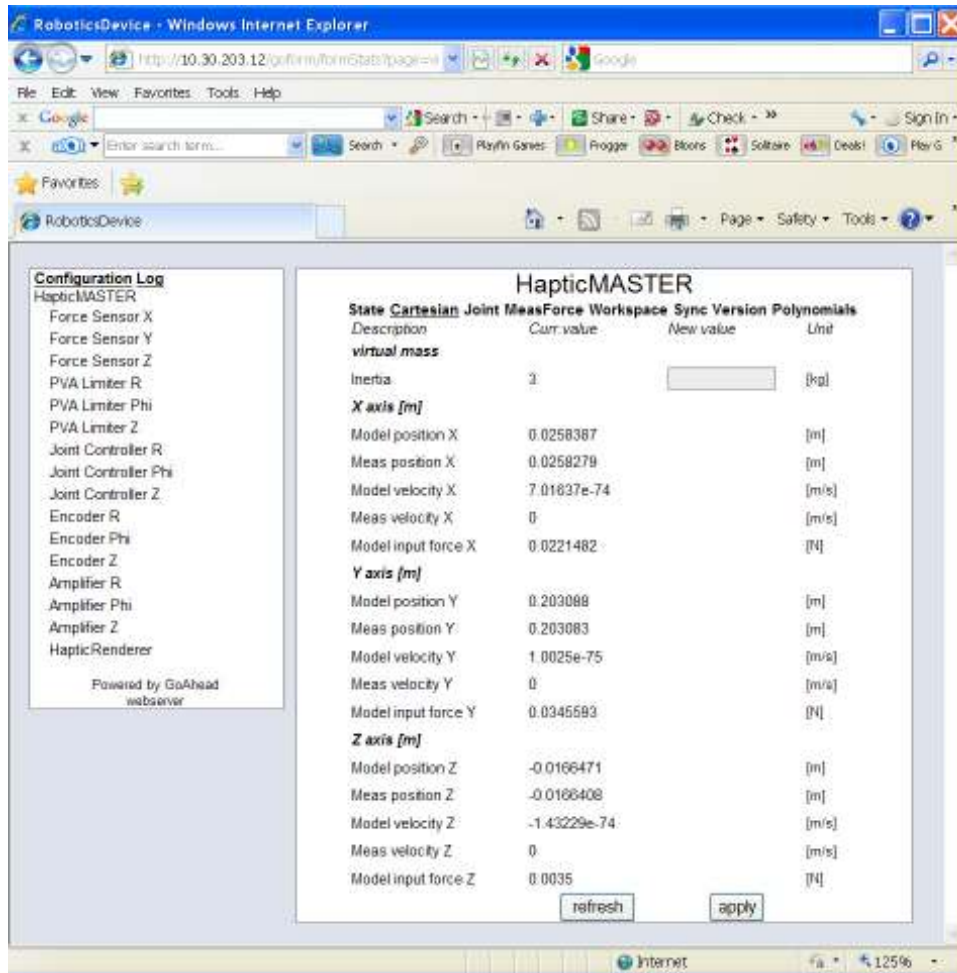
The current state of the device is displayed next to the *Device state* field.

When you wish to change the current state, you click on the **start** button next to the desired state. For example, if you want to initialize the HapticMASTER (search its end stops), you click on the **start** button next to *Set to INIT*. The HapticMASTER then initializes by searching the end stops on all three axes. You can click the **refresh** button to monitor the *Device state* variable during initialization. When the initialization finishes, the state will transit to STOP.

To calibrate the force sensor, click on the **start** button next to *CalibrateForceSensor*. Make sure you do not touch the force sensor itself when clicking the button.

6.6 Changing the Virtual Mass

To change the virtual mass of the End Effector, click the *HapticMASTER* option in the menu. Then choose the *Cartesian* tab from the right panel. The following screen appears:



Enter another virtual mass in the input field (in [Kg]). Click the **apply** button.

The value you entered will be copied to the HapticMASTER device and should appear under the *Curr. value* column. You should feel that moving the End Effector is influenced by the virtual mass change.

7. Operating the HM

For a proper use of the HapticMASTER, the following conditions must be met during operation.

7.1 Maximum end effector forces

The force sensor at the front end of robot arm is limited by end stops to prevent overload. The maximum safe force at the end effector is 100 N (approximately 10 kg). Only within this force range proper operation of the HapticMASTER is guaranteed.

7.2 Maximum robot forces

To guarantee a large rendered stiffness range at the end effector, the robot arm is designed to resist large forces, up to 250 N. Illustrative is that a human subject can gently lean on the arm of the HapticMASTER momentarily, without the operator noticing the difference in performance at the end effector.

It needs to be noted that continuous loading of the HapticMASTER might have consequences on the life span. Loading the actuators and the mechanisms inside the HapticMASTER more heavily than during 'normal operation', e.g. merely loading the HapticMASTER at the end effector, the mechanical components might wear out faster. If the HapticMASTER is used other than in 'normal operation', please contact your vendor if there will be any consequences for the warranty on your HapticMASTER.

7.3 Holding the end effector

The end effector can be held in anyway that the operator pleases (see Figure 7-1 and Figure 7-2). From experience it can be stated that a light grip gives an optimal haptic sensation.



Figure 7-1 Correct operation 1



Figure 7-2 Correct operation 2

However, the end effector must not be held in combination with other parts of the robot! This implies that also the collar of the robot arm must not be held. Figure 7-3 and Figure 7-4 illustrate ways not to operate the HapticMASTER. These ways of holding might cause instability due to tactile mismatch for the operator.



Figure 7-3 Wrong operation 1



Figure 7-4 Wrong operation 2

7.4 End effector contact with the environment

By default the control loop of the HapticMASTER is tuned for an interaction with a human individual. Stable interaction between the HapticMASTER and a very stiff environment will require a higher setting of the virtual mass. This can be achieved by using the Web Interface.

7.5 Using the emergency button

When the emergency button is pressed, an emergency circuit will cut off the power to the robot arm. The robot will instantly become numb.

Releasing the emergency switch, and pressing the green reset button at the back of the control box puts the power back on to the robot. Keep in mind that the software has detected the use of the emergency switch, and goes to the OFF state. This causes the active application to stop. An initialization procedure, as described in chapter 8, is required to use the robot again.

7.6 Customized end effectors

You can mount your own end effectors on the Force sensor of the HapticMASTER, but take the following in mind:



Please consult MOOG for the design of a customized end effector. Damage due to customized end effectors that are not approved by MOOG will void warranty

- End effectors should be as light as possible (less than 1.5 kg). High mass can lead to instability and damage to the force sensor.
- The end effector should not exert torques on the force sensor. Therefore the centre of mass of the end effector should be as close to the force sensor plate as possible (less than 100 mm).
- End effectors should not have direct or indirect mechanical links (guidance linkages, table supports) with the lab environment.
- For a drawing scheme of the holes in the force sensor see section A.2

- End effectors should not bridge the gap between the force sensor and the device itself in any way, with the possible exception of very soft, light weight electrical cable in a wide loop.
- Mount the end effector with M4 bolts no longer than 8 mm. Longer bolts can damage the internals of the force sensor.
- Before first use, increase the virtual mass of the HapticMASTER by at least the mass of the end effector, and for first tests by at least double that margin.
- High physical masses at the force sensor can lead to instability. High virtual mass will prevent this instability. See section 6.6 for changing the virtual mass

8. First use of the HapticMASTER



Before using the HapticMASTER for the first time, make sure you have read all previous sections!!

Verify the emergency button is not activated (not pressed)

When the emergency button is pressed, it cuts off the power to the robot arm through an emergency circuit. The button can be released again by turning the red knob clockwise, till it pops back up.

Turning on the electricity

Turn on the HapticMASTER by switching the power switch at the back of the electronics box to 'I'. The electronics box will start up, indicated by a beep.

Activating the HapticMASTER

Now activate the robot arm by pressing the green reset button at the back of the control box. You will hear a click from the safety relay, indicating that the power is on.

Initializing the HM

Before the HapticMASTER can be operated, it needs to initialize. During initialization the HapticMASTER will slowly move through its complete workspace, calibrating itself.



During the initialization the force sensor must not be touched!

All included HapticMASTER demos will automatically initialize immediately after the demo is started. After the initialization, the HapticMASTER is ready for use.

Executing one of the demos

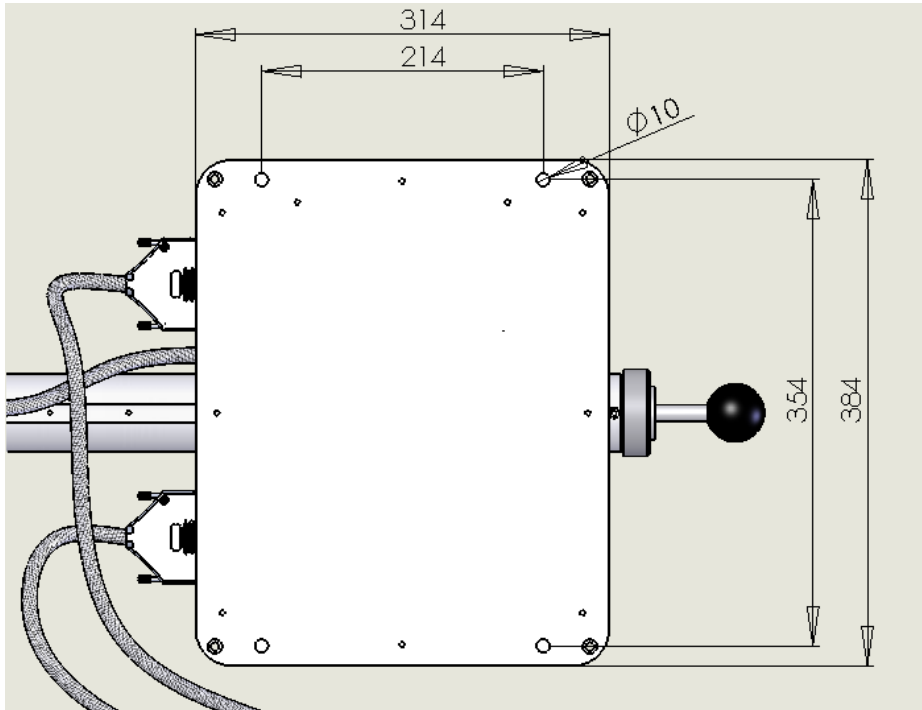
By double-clicking the *.exe file of the selected demo, the robot will initialize automatically. After the robot has stopped its initialization movements, the demo will appear on screen and the robot is free to move. Use the menu on the upper right side of the screen to activate the haptic rendering and change the haptic parameters. Press and hold the left- or right mouse button and move the mouse to orientate and zoom in or out.

Enjoy.

Appendix A. Dimensions

A.1 Bottom plate

The HapticMASTER contains holes for mounting it on a base. See picture below



A.2 Mounting holes on force sensor

The force sensor contains holes for mounting end effectors. The location of the holes is given in the picture below. For all generations of force sensors, the holes are at the same location. The thread depth is 8 mm. Longer bolts can damage the internals of the force sensor

