

OPENHAPTICS[®] TOOLKIT

version 3.0

API REFERENCE MANUAL



Open Haptics® Toolkit

version 3.0

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Preface

This manual is meant to be used as a companion to the *OpenHaptics® Toolkit Programmer's Guide*. It contains reference pages to all the OpenHaptics® toolkit HDAPI and HLAPI functions and types as well as appendices with tables that describe all the parameters. Functions are listed alphabetically by section.

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For the QuickHaptics™ micro API, a detailed description of classes and functions with links to code examples is provided in online Doxygen format in the DSC and not in this guide.

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; an argument.	See the <i>User Manual</i> .
BoldFace	Function name or parameter embedded in text.	capabilities are set using hdEnable()
Courier	Identifies code.	<code>void hlEnable()...</code>
Note, Warning, Important	Calls out important additional information.	Note: See table...

Note Code snippets in this document may include hard and soft line breaks for formatting purposes.

PREFACE

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Section I: HDAPI Routines

1

Device Routines

The following are routines for managing the device and forces. This includes all functionality for initializing devices, querying and setting device state, and turning capabilities on or off.

hdBeginFrame

Description: Begins an haptics frame, which is a block of code within which the device state is guaranteed to be consistent. Updates state from the device for current/last information. All state-related information, such as setting state, should be done within a haptics frame.

Syntax: `void hdBeginFrame(HHD hHD)`

Argument	Definition
hHD	The device handle of an initialized device.

Returns: None

Usage: Typically the first haptics call per device per scheduler tick. For example, if two haptics devices are being managed, **hdBeginFrame()** should be called for each of them before device-specific calls are made. Only one frame is allowed per device per scheduler tick unless `HD_ONE_FRAME_LIMIT` is disabled. However, frames for the same device can be nested within a scheduler tick. This function automatically makes the supplied device current.

Note: Not all devices support turning off `HD_ONE_FRAME_LIMIT`. Doing so may lead to unpredictable behavior.

Example:

```
HHD hHD = hdGetCurrentDevice;  
hdBeginFrame(hHD);
```

Errors: `HD_ILLEGAL_BEGIN` if a frame was already completed for the current device within the current scheduler tick.

See also: `hdMakeCurrentDevice`, `hdDisable`, `hdIsEnabled`

hdDisable

Description: Disables a capability.

Syntax: `void hdDisable(HDenum cap)`

Argument	Definition
cap	The capability to disable. For a list of the capabilities see Table A-10, “hdEnable, hdDisable Parameters,” on page A-11.

Returns: None

Usage: Capabilities are typically related to safety mechanisms. Use extreme caution when disabling safety features.

Example: `hdDisable(HD_MAX_FORCE_CLAMPING);`

Errors: HD_INVALID_ENUM if *cap* does not support **hdEnable()** or **hdDisable()**.

See Also: `hdEnable`, `hdIsEnabled`

hdDisableDevice

Description: Disables a device. The handle should not be used afterward.

Syntax: `void hdDisableDevice(HHD hHD)`

Argument	Definition
hHD	The device handle of an initialized device.

Returns: None

Usage: Call during cleanup when done using a device. Typically the last call after stopping the scheduler and uncheduling all scheduled callbacks.

Examples: `hdStopScheduler();`
`hdUnschedule(scheduleCallbackHandle);`
`hdDisableDevice(hdGetCurrentDevice());`

Errors: None

See also: `hdInitDevice`, `hdStopScheduler`

hdEnable

Description: Enables a capability.

Syntax: `void hdEnable(HDenum cap)`

Argument	Definition
cap	The capability to enable. For a list of the capabilities see Table A-10, “hdEnable, hdDisable Parameters,” on page A-11.

Returns: None

Usage: Capabilities are typically related to safety mechanisms. Most are turned on by default.

Example: `hdEnable(HD_FORCE_OUTPUT);`

Errors: HD_INVALID_ENUM if *cap* does not support enable/disable.

See also: hdDisable, hdIsEnabled

hdEndFrame

Description: Ends a haptics frame. Causes forces and other states to be written to the device. An **hdBeginFrame()** and **hdEndFrame()** should always be paired within the same scheduler tick.

Syntax: `void hdEndFrame(HHD hHD)`

Argument	Definition
hHD	The device handle of an initialized device.

Returns: None

Usage: Typically the last haptics call per device, per scheduler tick.

Example: `hdEndFrame(hdGetCurrentDevice());`

Errors: HD_ILLEGAL_END if this call is not paired correctly with an **hdBeginFrame()** of the same device handle.

See also: hdBeginFrame, hdMakeCurrentDevice

hdGet (Parameter Values)

Description: Obtains information about the device. There are five query functions for obtaining information about the device associated with the parameter name used.

Syntax:

```
void hdGetBooleanv(HDenum pname, HDboolean *params)  
void hdGetIntegerv(HDenum pname, HDint *params)  
void hdGetFloatv(HDenum pname, HDfloat *params)  
void hdGetDoublev(HDenum pname, HDdouble *params)  
void hdGetLongv(HDenum pname, HDlong *params)
```

Argument	Definition
pname	Parameter name to use.
params	Array where the results will be returned. For a list of parameters see Table A-1, “hdGet Parameters,” on page A-2.

Returns: None

Usage: Primary function for getting device information. Depending on the parameter, one should use the appropriate params type, and therefore the appropriate function signature. The caller of the function has the responsibility for allocating memory. These functions should only be called within a haptics frame.

Example:

```
HDdouble position[3];  
hdGetDoublev(HD_CURRENT_POSITION, position);  
  
HDint buttons;  
hdGetIntegerv(HD_CURRENT_BUTTONS, &buttons);
```

Errors:

- HD_INVALID_INPUT_TYPE if *pname* does not support the input type.
- HD_INVALID_ENUM if *pname* does not support **hdGet()**.

See also: hdSet (Parameter Values)

hdGetCurrentDevice

Description:	Gets the handle of the current device.
Syntax:	<code>HHD hdGetCurrentDevice()</code>
Returns:	The handle of the current device.
Usage:	Primarily used in multi-device applications to keep track of which device is current, or for calls that require a device handle.
Example:	<pre>HHD hHD = hdGetCurrentDevice();</pre>
Errors:	HD_INVALID_HANDLE if no device is current, for example, if no device has been initiated yet.
See also:	hdMakeCurrentDevice

hdGetError

Description:	Returns errors in order from most recent to least. Each call retrieves and removes one error from the error stack. If no error exists, this function returns a HDErrorInfo with HD_SUCCESS as its code. HDErrorInfo contains the error code from the defines file, the handle of the device that was active when the error occurred, and the device's original internal error code. The internal code can be used for obtaining additional support from the device vendor.
Syntax:	<code>HDErrorInfo hdGetError()</code>
Returns:	HDErrorInfo. This data structure is a typedef in hdDefines.h. It exposes information on the handle of the device, an errorCode, and an internal error code. See Table A-15, “Device Error Codes,” on page A-13 for a list of errorCodes and descriptions.
Usage:	Intersperse in code to occasionally check for errors.
Example:	<pre>HDErrorInfo error; error = hdGetError(); if (HD_DEVICE_ERROR(error)) // do error handling hdGetErrorString(error.errorCode);</pre>
Errors:	None
See also:	hdGetErrorString, HDErrorInfo Type

hdGetErrorString

Description: Returns information about an error code.

Syntax: HDstring hdGetErrorString(HDerror *errorCode*)

Argument	Definition
<i>errorCode</i>	An error code from <code>hdDefines</code> .

Returns: A readable string representing the explanation of the error code.

Usage: Obtains useful information about error codes. The return string is static and should not be deallocated using **Free** or **Delete** or any similar function.

Example: `hdGetErrorString(HD_FRAME_ERROR);`

Errors: None

See also: `hdGetError`, `HD_DEVICE_ERROR`

hdGetString

Description: Gets a string value for the associated parameter name.

Syntax: HDstring hdGetString(HDenum *pname*)

Argument	Definition
<i>pname</i>	Parameter name to use. For a list what types and how many values are used by each parameter name, see Table A-3, “Get Identification Parameters,” on page A-4. Note that not all parameter names support string values.

Returns: Requested string associated with the parameter name.

Usage: Gets readable string information about device properties, such as the device model type. The return string is static and should not be deallocated using **Free** or **Delete** or any similar function.

Example: `HDstring *deviceType = hdGetString(HD_DEVICE_MODEL_TYPE);`

Errors:

- `HD_INVALID_INPUT_TYPE` if *pname* does not support string as an input type.
- `HD_INVALID_ENUM` if *pname* does not support **hdGetString()**.

hdInitDevice

Description: Initializes the device. If successful, this returns a handle to the device and sets the device as the current device.

Syntax: `HHD hdInitDevice(HDstring pConfigName)`

Argument	Definition
<code>pConfigName</code>	The name of the device, such as the name found under the control panel “Phantom Configuration”. If <code>HD_DEFAULT_DEVICE</code> is passed in as <code>pConfigName</code> , hdInitDevice() will initialize the first device that it finds.

Returns: A handle to the initialized device.

Usage: Generally the first haptics command that should be issued.

Example: `HHD hDevice = hdInitDevice("Default PHANTOM");`

Errors:

- `HD_DEVICE_ALREADY_INITIATED` if the device was already initiated.
- `HD_DEVICE_FAULT` if the device could not be initiated, for example, if `pConfigName` is invalid.

See also: `hdDisableDevice`, `hdMakeCurrentDevice`, `hdStartScheduler`

hdIsEnabled

Description: Checks if a capability is enabled. Capabilities are in `hdDefines.h` file under the `enable/disable` category.

Syntax: `HDboolean hdIsEnabled(HDenum cap)`

Argument	Definition
<code>cap</code>	Capability to check. For a list of the capabilities see Table A-10, “ <code>hdEnable</code> , <code>hdDisable</code> Parameters,” on page A-11.

Returns: Whether the capability is enabled.

Usage: Capabilities are typically related to safety mechanisms. Most are turned on by default.

Example: `HDboolean bForcesOn = hdIsEnabled(HD_FORCE_OUTPUT);`

Errors: `HD_INVALID_ENUM` if `cap` does not support `enable/disable`.

See also: `hdEnable`, `hdDisable`

hdMakeCurrentDevice

Description: Makes the device current. All subsequent device-specific actions such as getting and setting state or querying device information will be performed on this device until another is made current.

Syntax: `void hdMakeCurrentDevice(HHD hHD)`

Argument	Definition
<code>hHD</code>	The device handle of an initialized device.

Returns: None

Usage: Primarily used to switch between devices in multi-device applications.

Example:

```
hdBeginFrame(hHD1);  
hdGetDoublev(HD_CURRENT_POSITION, p1);  
hdBeginFrame(hHD2);  
hdGetDoublev(HD_CURRENT_POSITION, p2);  
calculateforce(p1,p2,outforce1,outforce2);  
hdMakeCurrentDevice(hHD1);  
hdSetDoublev(HD_CURRENT_FORCE,outforce1);  
hdEndFrame(hHD1);  
hdMakeCurrentDevice(hHD2);  
hdSetDoublev(HD_CURRENT_FORCE,outforce2);  
hdEndFrame(hHD2);
```

Errors: HD_INVALID_HANDLE if *hHD* does not refer to an initiated device.

See also: `hdInitDevice`

hdSet (Parameter Values)

Description: Sets information associated with the parameter name.

Syntax:

```
void hdSetBooleanv(HDenum pname, const HDboolean *params)
void hdSetIntegerv(HDenum pname, const HDint *params)
void hdSetFloatv(HDenum pname, const HDfloat *params)
void hdSetDoublev(HDenum pname, const HDdouble *params)
void hdSetLongv (HDenum pname, const HDlong *params)
```

Argument	Definition
pname	Parameter name to set.
params	Array of values to set. For a list of parameters see Tables in “Set Parameters,” on page A-8.

Returns: None

Usage: Primary function for sending information to the device or changing device properties. Depending on the parameter, one should use the appropriate params type, and therefore the appropriate function signature. The caller of the function has the responsibility for allocating memory. These functions should only be called within a haptics frame.

Example:

```
HDfloat forces[3] = { 2, .5, 0};
hdSetFloatv(HD_CURRENT_FORCE, forces);
```

Or,

```
hduVector3Dd forces(0.2, 0.5, 0);
hdSetFloatv(HD_CURRENT_FORCE, forces);
```

Errors:

- HD_INVALID_INPUT_TYPE if *pname* does not support the input type.
- HD_INVALID_ENUM if *pname* does not support *hdSet*.

See also: *hdGet (Parameter Values)*.

HD_DEVICE_ERROR

Description: A macro useful for checking if an error has occurred.
`#define HD_DEVICE_ERROR(X)((X).errorCode)!=HD_SUCCESS)`

Syntax: `int HD_DEVICE_ERROR(x)`

Argument	Definition
X	The error structure to check. Error structure is of type HErrorInfo.

Returns: 1 if error, 0 if no error

Usage: Typically, call this with **hdGetError()** to check if the error stack contains an error.

Example:

```
HErrorInfo error;
if (HD_DEVICE_ERROR(error = hdGetError()))
{
    hduPrintError(stderr, &error, "HDAPI device error encountered");
    return -1;
}
```

Errors: None

See also: `hdGetError`, `hdGetErrorString`

2

Calibration Routines

This chapter covers the routines used for managing the calibration of the device. Calibration is necessary for accurate position mapping and force/torque rendering of the haptic device; calibration synchronizes the software's notion of the device position with the actual mechanical position. For example, if the device is not calibrated, then the software may believe the device position is in the corner of the workspace while the actual device arm is in the center of its workspace.

A typical application begins by asking the user to put the device in a neutral position or inkwell so that it can be calibrated. Some devices automatically calibrate so that this step is unnecessary.

The calibration interface provides functions for querying the calibration style(s) supported by the device, checking the calibration status, and updating the calibration.

Querying Calibration Styles

Supported calibration styles differ depending on device. The list of calibration styles is:

HD_CALIBRATION_ENCODER_RESET: The device position must be read while the device is in a specified neutral position. For devices that use encoder reset calibration style, typically the user is asked to place the device in the neutral position at the start of the application so that position can be sampled. PHANTOM® premium haptic device models use encoder reset.

HD_CALIBRATION_INKWELL: The device must be placed into the device's inkwell to be calibrated. The PHANTOM Omni® haptic device supports inkwell calibration.

HD_CALIBRATION_AUTO: The device automatically calibrates by collecting positional data while the user moves the device arm around. This data persists between sessions so the device does not need to be repeatedly calibrated. The PHANTOM® Desktop™ haptic device supports auto calibration.

The calibration styles that a particular device supports can be obtained as follows:

```
HDint supportedStyles;  
hdGetIntegerv(HD_CALIBRATION_STYLE, &supportedStyles);
```

It is possible for a device to support more than one calibration style. The supportedStyles value should be masked (&) with HD_CALIBRATION_ENCODER_RESET, HD_CALIBRATION_INKWELL, HD_CALIBRATION_AUTO to determine if each particular style is supported.

hdCheckCalibration

- Description:** Checks the calibration status.
- If the return value is HD_CALIBRATION_OK, the device is already calibrated.
 - If the return value is HD_CALIBRATION_NEEDS_UPDATE, call **hdUpdateCalibration()** to update the calibration.
 - If the return value is HD_CALIBRATION_NEEDS_MANUAL_INPUT, the user needs to provide additional input particular to the calibration style.
- Syntax:** HDenum hdCheckCalibration()
- Returns:** Possible values are:
- HD_CALIBRATION_OK
 - HD_CALIBRATION_NEEDS_UPDATE
 - HD_CALIBRATION_NEEDS_MANUAL_INPUT
- Usage:** For devices that support auto calibration, call intermittently so that the device continues to update its calibration.
- Example:**
- ```
if (hdCheckCalibration() == HD_CALIBRATION_NEEDS_UPDATE)
{
 hdUpdateCalibration(myStyle);
}
```
- Errors:** HD\_DEVICE\_FAULT if the calibration information could not be obtained from the device.
- See Also:** hdUpdateCalibration



## hdUpdateCalibration

**Description:** Calibrates the device. The type of calibration supported can be queried through getting HD\_CALIBRATION\_STYLE.

**Syntax:** void hdUpdateCalibration(HDenum style)

| Argument | Definition                                                                                                                         |
|----------|------------------------------------------------------------------------------------------------------------------------------------|
| style    | The calibration style of the device. For a list of calibration styles see Table A-3, “Get Identification Parameters,” on page A-4. |

**Returns:** None

**Usage:** Calibrate the device when **hdCheckCalibration()** returns HD\_CALIBRATION\_NEEDS\_UPDATE.

**Example:**

```
HDint style;
hdGetIntegerv(HD_CALIBRATION_STYLE, &style);
hdUpdateCalibration(style);
```

**Errors:** HD\_DEVICE\_FAULT if the calibration type could not be performed on the device.

**See Also:** hdCheckCalibration

2 CALIBRATION ROUTINES  
*hdUpdateCalibration*

---

# 3

---

## Scheduler Routines

The following are routines for managing the scheduler and scheduler routines. This includes starting and stopping the scheduler, adding callbacks into the scheduler, and managing those callbacks.

---

### hdGetSchedulerTimeStamp

**Description:** Returns the elapsed time since the start of the servo loop tick. This is useful for measuring duty cycle of the servo loop.

**Syntax:** `HDdouble hdGetSchedulerTimeStamp()`

**Returns:** Number of seconds since the start of the servo loop tick.

**Usage:** Used to check how long operations have taken.

**Example:**

```
HDCallbackCode HDCALLBACK schedulerTimeCallback(void *pUserData)
{
 HDdouble *schedulerTime = (HDdouble *)pUserData;
 *schedulerTime = hdGetSchedulerTimeStamp();
 return HD_CALLBACK_DONE;
}

HDdouble schedulerTime;
hdScheduleSynchronous(schedulerTimeCallback, &schedulerTime,
 HD_MAX_SCHEDULER_PRIORITY);
```

**Errors:** None

**See also:** None

## hdScheduleAsynchronous

**Description:** Schedules an operation to be executed by the scheduler in the servo loop, and does not wait for its completion. Scheduler callbacks submitted from the servo loop thread are run immediately regardless of priority.

**Syntax:**

```
HDSchedulerHandle
hdScheduleAsynchronous(HDSchedulerCallback pCallback,
 void *pUserData,
 HDushort nPriority)
```

| Argument  | Definition                                                                                                       |
|-----------|------------------------------------------------------------------------------------------------------------------|
| pCallback | The function callback.                                                                                           |
| pUserData | The data to be used by the function.                                                                             |
| nPriority | The priority of the operation. Callbacks are processed once per scheduler tick, in order of decreasing priority. |

**Returns:** Handle for the operation.

**Usage:** Typically used for scheduling callbacks that run every tick of the servo loop. For example, one can run a dynamic simulation within an asynchronous callback and set forces within that simulation.

**Example:**

```
HDCallbackCode HDCALLBACK mySchedulerCallback(void *pUserData)
{
 HDint buttons;
 hdGetIntegerv(HD_CURRENT_BUTTONS, &buttons);
 if (buttons == 0)
 return HD_CALLBACK_CONTINUE;
 return HD_CALLBACK_DONE;
}
...
HDSchedulerHandle hHandle =
hdScheduleAsynchronous(mySchedulerCallback,
 (void*)0, HD_DEFAULT_SCHEDULER_PRIORITY);
```

**Errors:**

- **HD\_SCHEDULER\_FULL** if the scheduler has reached its upper limit on the number of scheduler operations that it can support at once.
- **HD\_INVALID\_PRIORITY** if *nPriority* is out of range, i.e. less than **HD\_MIN\_SCHEDULER\_PRIORITY** or greater than **HD\_MAX\_SCHEDULER\_PRIORITY**.

**See also:** HDSchedulerCallback Type, hdStartScheduler

---

## hdScheduleSynchronous

**Description:** Schedules an operation to be executed by the scheduler in the servo loop, and waits for its completion. Scheduler callbacks submitted from the servo loop thread are run immediately regardless of priority.

**Syntax:**

```
void hdScheduleSynchronous(HDSchedulerCallback pCallback,
 void *pUserData,
 HDushort nPriority)
```

| Argument  | Definition                                                                                                       |
|-----------|------------------------------------------------------------------------------------------------------------------|
| pCallback | The function callback.                                                                                           |
| pUserData | The data to be used by the function.                                                                             |
| nPriority | The priority of the operation. Callbacks are processed once per scheduler tick, in order of decreasing priority. |

**Returns:** None

**Usage:** Typically used as a synchronization mechanism between the servo loop thread and other threads in the application. For example, if the main application thread needs to access the position or button state, it can do so through a synchronous scheduler call. Can be used for synchronously copying state from the servo loop or synchronously performing an operation in the servo loop.

**Example:**

```
HDCallbackCode HDCALLBACK buttonCallback(void *pUserData)
{
 int *buttons = (int *)pUserData;
 hdGetIntegerv(HD_CURRENT_BUTTONS, buttons);
 return HD_CALLBACK_DONE;
}

int buttons;
HDSchedulerHandle hHandle =
 hdScheduleSynchronous(buttonCallback, &buttons,
 HD_DEFAULT_SCHEDULER_PRIORITY);
```

**Errors:**

- HD\_SCHEDULER\_FULL if the scheduler has reached its upper limit on the number of scheduler operations that it can support at once.
- HD\_INVALID\_PRIORITY if *nPriority* is out of range, i.e. less than HD\_MIN\_SCHEDULER\_PRIORITY or greater than HD\_MAX\_SCHEDULER\_PRIORITY.

**See also:** HDSchedulerCallback Type, hdStartScheduler

## hdSetSchedulerRate

**Description:** Sets the number of times the scheduler ticks its callbacks per second.

**Syntax:** `void hdSetSchedulerRate(HDulong nRate)`

| Argument | Definition                                         |
|----------|----------------------------------------------------|
| nRate    | The requested rate for the scheduler to run in Hz. |

**Returns:** None

**Usage:** Typically used to control the fidelity of force rendering. Most haptic applications run at 1000Hz. PCI and EPP support 500, 1000, and 2000 Hz. Firewire supports 500, 1000, 1600 Hz, plus some increments in between based on the following expression:  $\text{floor}(8000/N + 0.5)$ .

As a word of caution, decreasing the rate can lead to instabilities and kicking. Increasing the servo loop rate can yield stiffer surfaces and better haptic responsiveness, but leaves less time for scheduler operations to complete. When setting the scheduler rate, check **hdGetSchedulerTimeStamp()** and **HD\_INSTANTANEOUS\_UPDATE\_RATE** to verify that the servo loop is able to maintain the rate requested.

Some devices may support a variety of settings. Certain devices may need to be flashed with the latest firmware to be able to use this feature. You can find current information from the SensAble Developer Support Center, see “Preface” for information about the DSC.

**Example:**

```
// try to set rate of 500 Hz
hdSetSchedulerRate(500);
```

**Errors:** **HD\_INVALID\_VALUE** if the *nRate* specified cannot be set.

**See also:** `hdGetSchedulerTimeStamp`

## hdStartScheduler

|                     |                                                                                                                                                                                                                                                                                                                                        |
|---------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Description:</b> | Starts the scheduler. The scheduler manages callbacks to be executed within the servo loop thread.                                                                                                                                                                                                                                     |
| <b>Syntax:</b>      | <code>void hdStartScheduler()</code>                                                                                                                                                                                                                                                                                                   |
| <b>Returns:</b>     | None                                                                                                                                                                                                                                                                                                                                   |
| <b>Usage:</b>       | Typically call this after all device initialization routines and after all asynchronous scheduler callbacks have been added. There is only one scheduler, so it needs to be started once, no matter how many devices one is using. Execution of callbacks starts when the scheduler is started. Forces are enabled at this point also. |
| <b>Example:</b>     | <code>hdStartScheduler();</code>                                                                                                                                                                                                                                                                                                       |
| <b>Error:</b>       | HD_TIMER_ERROR if the servo loop thread could not be initialized or the servo loop could not be started.                                                                                                                                                                                                                               |
| <b>See also:</b>    | hdStopScheduler                                                                                                                                                                                                                                                                                                                        |

---

## hdStopScheduler

|                     |                                                                                                                   |
|---------------------|-------------------------------------------------------------------------------------------------------------------|
| <b>Description:</b> | Stops the scheduler.                                                                                              |
| <b>Syntax:</b>      | <code>void hdStopScheduler()</code>                                                                               |
| <b>Returns:</b>     | None                                                                                                              |
| <b>Usage:</b>       | Typically call this as a first step for cleanup and shutdown of devices.                                          |
| <b>Examples:</b>    | <code>hdStopScheduler();<br/>hdUnschedule();<br/>hdUnschedule(myCallbackHandle);<br/>hdDisableDevice(hHD);</code> |
| <b>Error:</b>       | HD_TIMER_ERROR if the servo loop thread could not be initialized.                                                 |
| <b>See also:</b>    | hdUnschedule, hdDisableDevice                                                                                     |

## hdUnschedule

**Description:** Un-schedules an operation by removing the associated callback from the scheduler.

**Syntax:** `void hdUnschedule(HDSchedulerHandle hHandle)`

| Argument             | Definition                                                                                                                         |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------|
| <code>hHandle</code> | Handle for an active operation to be unscheduled, obtained via <b>hdScheduleAsynchronous()</b> or <b>hdScheduleSynchronous()</b> . |

**Returns:** None

**Usage:** Used to stop an active asynchronous operation. For example, if the application thread has created an asynchronous operation that returns `HD_CALLBACK_CONTINUE` to run indefinitely, the application can call **hdUnschedule()** to force the callback to terminate.

**Example:**

```
HDSchedulerHandle hHandle =
 hdScheduleAsynchronous(mySchedulerCallback,
 (void*)0, HD_DEFAULT_SCHEDULER_PRIORITY);
hdUnschedule(hHandle);
```

**Errors:** `HD_INVALID_OPERATION` if the scheduler operation associated with the handle has already terminated.

**See also:** `hdStopScheduler`, `hdScheduleAsynchronous`, `hdScheduleSynchronous`



---

## hdWaitForCompletion

**Description:** Checks if a callback is still scheduled for execution. This can be used as a non-blocking test or can block and wait for the callback to complete.

**Syntax:** HDboolean hdWaitForCompletion(HDSchedulerHandle *hHandle*,  
HDWaitCode *param*)

| Argument       | Definition                                          |
|----------------|-----------------------------------------------------|
| <i>hHandle</i> | Handle of the target active asynchronous operation. |
| <i>param</i>   | Either HD_WAIT_CHECK_STATUS or HD_WAIT_INFINITE.    |

**Returns:** Whether the callback is still scheduled.

- If HD\_WAIT\_CHECK\_STATUS is passed into *param*, returns true if the scheduler operation is still active.
- If HD\_WAIT\_INFINITE is passed into *param*, this function will return true if the wait was successful or false if the wait failed.

**Usage:** Can be used on an asynchronous operation to either check the status or to commit to waiting for the operation to finish.

**Example:**

```
HDSchedulerHandle hHandle =
 hdSchedulerAsynchronous(mySchedulerCallback,
 (void*) 0, HD_DEFAULT_SCHEDULER_PRIORITY);

/* Do some other work and then wait for the operation to complete */

HDboolean bWaitSuccess = hdWaitForCompletion(hHandle, HD_WAIT_
INFINITE);
```

**Errors:** None

**See also:** hdUnschedule, hdScheduleAsynchronous, hdScheduleSynchronous

3 SCHEDULER ROUTINES  
*hdWaitForCompletion*

---

# 4

---

## HDAPI Deployment

---

### hdDeploymentLicense

**Description:** Activates the deployment license issued to the application developer. Once the deployment license has been validated, it will remain active until the application is exited. It is not an error to call this more than once in an application session.

**Syntax:** `HDboolean hdDeploymentLicense (const char* vendorName, const char* applicationName, const char* password)`

| Argument        | Definition                                                     |
|-----------------|----------------------------------------------------------------|
| vendor          | The name of the organization to which the license is issued.   |
| applicationName | The name of the application the license is tied to.            |
| password        | The license string which authenticates the deployment license. |

**Returns:** Non-zero if the validation succeeded, zero if the validation failed.

**Usage:** Needs to be executed before **hdInitDevice** to operate correctly. **hdInitDevice** will fail if the deployment license is not valid. Note that if a developers license is present **hdInitDevice** will succeed.

**Example:**

```
HDboolean bValid = hdDeploymentLicense ("Haptic Co.",
 "Haptic Application", 6A12...);
```

**See also:** `hdDeploymentLicense`

4 HDAPI DEPLOYMENT  
*hdDeploymentLicense*

---

# 5

---

## HDAPI Types

The following are variable and function types used by the HDAPI.

---

### HDSchedulerCallback Type

**Description:** Scheduler operation function type, used to define operations to be run in the scheduler thread.

**Syntax:**

```
typedef HDCallbackCode (HDCALLBACK *HDSchedulerCallabck)
 (void *pUserData)
```

| Argument  | Definition                                                           |
|-----------|----------------------------------------------------------------------|
| pUserData | Data used by the operation, created when the operation is scheduled. |

**Returns:** HD\_CALLBACK\_DONE or HD\_CALLBACK\_CONTINUE depending on whether the operation is complete or should be executed again the next tick of the scheduler.

**Usage:** Scheduled by **hdSchedulerSynchronous()** or **hdScheduleAsynchronous()**, the operation is then run during the next scheduler tick, or immediately for synchronous operations if the scheduler has not been started. The return value controls whether the operation terminates after being run or runs again in the next scheduler tick. A periodic operation, i.e. one that is executed indefinitely, should return HD\_CALLBACK\_DONE when it is finally to be unscheduled.

**Example:**

```
HDCallbackCode HDCALLBACK renderForceCallback(void *pUserData)
{
 HDdouble beginTime = hdGetSchedulerTimeStamp();

 HHD hHD = hdGetCurrentDevice();
 hdBeginFrame(hHD);

 computeForce();

 hdEndFrame(hHD);

 HDdouble endTime = hdGetSchedulerTimeStamp();

 /* Compute the elapsed time within this callback */
 HDdouble callbackTime = endTime - beginTime;
}
```

---

## HDErrorInfo Type

- Description:** Error structure generated by HDAPI when it reports an error.
- Syntax:**
- ```
typedef struct
{
    HDError errorCode;
    int internalErrorCode;
    HHD hHD;
} HDErrorInfo;
```
- Usage:** Pushed onto the error stack whenever an error is generated. Query for errors by calling **hdGetError()**. *errorCode* corresponds to the general error enumerates found in `hdDefines.h`. *internalErrorCode* is an error code from the underlying device drives, which is useful when reporting a problem to a device vendor. *hHD* is the handle of the device that was active when the error occurred.
- If no error has occurred, querying **hdGetError()** will return HDError with HD_SUCCESS as the errorCode and other fields are arbitrary.
- See also:** hdGetError

HDSchedulerHandle Type

- Description:** A handle to scheduler operations.
- Syntax:** typedef unsigned long HDSchedulerHandle
- Returns:** None
- Usage:** A HDSchedulerHandle is returned whenever the user schedules a scheduler callback. It can be used for a variety of operations such as unscheduling the associated callback, checking the status of the callback, and waiting for the callback to complete.
- Example:**
- ```
HDSchedulerHandle handle = hdScheduleAsynchronous(
 MyServoForceCallbackFunction, 0, HD_MAX_SCHEDULER_PRIORITY);
...
hdUnschedule(handle);
```
- Errors:** None
- See also:** HDSchedulerCallback Type, hdScheduleSynchronous, hdScheduleAsynchronous, hdUnschedule, hdWaitForCompletion

## Section II: HLAPI Routines





---

# 5

---

## Context/Frame Management

---

### hlBeginFrame

- Description:** Begins a haptics rendering pass, that is, a block of code that sends primitives to the haptic device to be rendered. **hlBeginFrame()** updates the current state of the haptic device and clears the current set of haptics primitives being rendered in preparation for rendering a new or updated set of primitives. All haptic primitive rendering functions (that is, shapes and effects) must be made within a begin/end frame pair. **hlBeginFrame()** also updates the world coordinate reference frame used by the haptic rendering engine. By default, **hlBeginFrame()** samples the current `GL_MODELVIEW_MATRIX` from OpenGL® to provide a world coordinate space for the entire haptic frame. All positions, vectors and transforms queried through **hlGet\*()** or **hlCacheGet\*()** in the client or collision threads will be transformed into that world coordinate space. Typically, the `GL_MODELVIEW_MATRIX` contains just the world to view transform at the beginning of a render pass.
- Syntax:** `void hlBeginFrame()`
- Returns:** None
- Usage:** Typically, haptic primitives are specified just following (or just before) rendering of graphics primitives. **hlBeginFrame()** is called at the start of the haptics update, the primitives are specified, and then **hlEndFrame()** is called.
- Example:**
- ```
hlBeginFrame();
hlBeginShape(...);
...
hlEndShape();
hlEndFrame();
```
- Errors:** `HL_INVALID_OPERATION` if nested inside another **hlBeginFrame()** or if no haptic rendering context is active.
- See also:** `hlEndFrame`

hlContextDevice

- Description:** Sets the haptic device for the current rendering context.
- Syntax:** `void hlContextDevice(HHD hHD)`
- Returns:** None
- Parameters:** *hHD* - handle to haptic device or HD_INVALID_HANDLE to set no device.
- Usage:** Used to change which haptic device will be used with the current haptic rendering context. HD_INVALID_HANDLE can also be used to release the use of the device and deactivate haptic rendering.
- Example:**
- ```
HHD hHD1, hHD2;

...

// create context with first haptic device
HHLRC = hlCreateContext(hHD1);
hlMakeCurrent(hHLRC);

...

// switch to second device
hlContextDevice(hHD2);
```
- Errors:** HL\_INVALID\_OPERATION if nested inside another **hlBeginFrame()** or if no haptic rendering context is active.
- See also:** hlMakeCurrent, hlCreateContext, hlDeleteContext, hlGetCurrentContext, hlGetCurrentDevice
- 

## hlCreateContext

- Description:** Creates a new haptic rendering context. The haptic rendering context stores the current set of haptic primitives to be rendered as well as the haptic rendering state.
- Syntax:** `HHLRC hlCreateContext(HHD hHD);`
- | Argument | Definition                                      |
|----------|-------------------------------------------------|
| hHD      | Device handle to the initialized haptic device. |
- Returns:** HHLRC handle to haptic rendering context.
- Usage:** Called during program initialization after initializing the haptic device. HD\_INVALID\_HANDLE can be provided as the device handle in order to create the context in suspended state.

**Example:**

```

HErrorInfo error;
hHD = hdInitDevice(HD_DEFAULT_DEVICE);
if (HD_DEVICE_ERROR(error = hdGetError()))
{
 hduPrintError(stderr, &error, "Failed to initialize
 haptic device");
 exit(1);
}
hHLRC = hlCreateContext(hHD);
hlMakeCurrent(hHLRC);

```

**Errors:** None

**See also:** hlMakeCurrent, hlDeleteContext

---

## hlDeleteContext

**Description:** Deletes a haptic rendering context. The haptic rendering context stores the current set of haptic primitives to be rendered as well as the haptic rendering state.

**Syntax:** void hlDeleteContext(HHLRC hHLRC);

| Argument | Definition                                                                |
|----------|---------------------------------------------------------------------------|
| hHLRC    | Handle to haptic rendering context returned by <b>hlCreateContext()</b> . |

**Returns:** None

**Usage:** Called at program exit to end haptic rendering and deallocate memory.

**Example:**

```

hHLRC = hlCreateContext(hHD);
hlMakeCurrent(hHLRC);
...
hlMakeCurrent(NULL);
hlDeleteContext(hHLRC);

```

**Errors:** None

**See also:** hlMakeCurrent, hlCreateContext

## hlEndFrame

|                     |                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Description:</b> | Ends a haptics rendering pass, that is a block of code that sends primitives to the haptic device to be rendered. <b>hlEndFrame()</b> flushes the set of haptics primitives (that is, shapes, effects) specified since the last <b>hlBeginFrame()</b> to the haptics device. All haptic primitive rendering functions must be made within a begin/end frame pair. |
| <b>Syntax:</b>      | <code>void hlEndFrame()</code>                                                                                                                                                                                                                                                                                                                                    |
| <b>Returns:</b>     | None                                                                                                                                                                                                                                                                                                                                                              |
| <b>Usage:</b>       | Typically, haptic primitives are specified just following (or just before) rendering of graphics primitives. <b>hlBeginFrame()</b> is called at the start of the haptics update, the primitives are specified, and then <b>hlEndFrame()</b> is called.                                                                                                            |
| <b>Example:</b>     | <pre>hlBeginFrame();<br/>hlBeginShape(...);<br/>...<br/>hlEndShape();<br/>hlEndFrame();</pre>                                                                                                                                                                                                                                                                     |
| <b>Errors:</b>      | HL_INVALID_OPERATION if not preceded by an <b>hlBeginFrame()</b> , if inside an <b>hlBeginShape()/hlEndShape()</b> block, or if no rendering context is active.                                                                                                                                                                                                   |
| <b>See also:</b>    | hlBeginFrame                                                                                                                                                                                                                                                                                                                                                      |

---

## hlGetCurrentContext

|                     |                                                                                                                 |
|---------------------|-----------------------------------------------------------------------------------------------------------------|
| <b>Description:</b> | Returns a handle to the currently active haptic rendering context for a given thread.                           |
| <b>Syntax:</b>      | <code>HHLRC hlGetCurrentContext(void)</code>                                                                    |
| <b>Returns:</b>     | Handle to currently active rendering context for the current thread or NULL if no context is active.            |
| <b>Parameters:</b>  | None                                                                                                            |
| <b>Usage:</b>       | Used to query which haptic rendering context is active for a given thread.                                      |
| <b>Example:</b>     | <pre>HHLRC hHLC = hlGetCurrentContext();<br/>if (hHLC != myHLC)<br/>{<br/>    hlMakeCurrent(myHLC);<br/>}</pre> |
| <b>Errors:</b>      | None                                                                                                            |
| <b>See also:</b>    | hlMakeCurrent, hlCreateContext, hlDeleteContext, hlContextDevice, hlGetCurrentContext                           |

## hlGetCurrentDevice

**Description:** Returns a handle to the haptic device for the currently active haptic rendering context.

**Syntax:** `HHD hlGetCurrentDevice(void);`

**Returns:** Handle to haptic device for currently active rendering context for the current thread or `HD_INVALID_HANDLE` if no context is active or no haptic device is selected for the current context.

**Parameters:** None

**Usage:** Used to query which haptic device is active for the current context.

**Example:**

```
HHD hHD = hlGetCurrentDevice();
if (hHD == HD_INVALID_HANDLE)
{
 hlContextDevice(myHD);
}
```

**Errors:** None

**See also:** `hlMakeCurrent`, `hlCreateContext`, `hlDeleteContext`, `hlContextDevice`, `hlGetCurrentContext`

## hlMakeCurrent

**Description:** Makes a haptic rendering context current. The current rendering context is the target for all rendering and state commands. All haptic rendering commands will be sent to the device in the current context until a context with a different device is made current.

**Syntax:** `void hlMakeCurrent (HHLRC hHLRC)`

| Argument | Definition                                                                    |
|----------|-------------------------------------------------------------------------------|
| hHLRC    | The handle to haptic rendering context returned by <b>hlCreateContext()</b> . |

**Returns:** None

**Usage:** Called at program startup after creating the rendering context or called during program execution to switch rendering contexts in order to render to multiple haptic devices.

**Example:**

```
HDeviceInfo error;
hHD = hdInitDevice(HD_DEFAULT_DEVICE);
if (HD_DEVICE_ERROR(error = hdGetError()))
{
 hduPrintError(stderr, &error, "Failed to initialize haptic
 device");
 exit(1);
}
hHLRC = hlCreateContext(hHD);
hlMakeCurrent(hHLRC);
```

**Errors:** None

**See also:** `hlCreateContext`, `hlDeleteContext`

---

# 6

---

## State Maintenance and Accessors

---

### hlEnable, hlDisable

**Description:** Enables or disables a capability for the current rendering context.

**Syntax:**

```
void hlEnable(HLenum cap);
void hlDisable(HLenum cap);
```

| Argument | Definition                                                                                                                 |
|----------|----------------------------------------------------------------------------------------------------------------------------|
| cap      | Capability to enable. For a list of possible capabilities see, Table B-9, “hlEnable, hlDisable, hlIsEnabled,” on page B-9. |

**Returns:** None

**Usage:** Enables or disables the capability specified.

**Example:**

```
hlDisable(HL_PROXY_RESOLUTION);
hlProxydv(HL_PROXY_POSITION, newProxyPos);
```

**Errors:** HL\_INVALID\_ENUM if *cap* is not one of the values listed.

**See also:** hlIsEnabled

## hlGetBooleanv, hlGetDoublev, hlGetIntegerv

**Description:** Allow querying of the different state values of the haptic renderer.

**Syntax:**

```
void hlGetBooleanv(HLenum pname, HLboolean *params)
void hlGetDoublev(HLenum pname, HLdouble *params)
void hlGetIntegerv(HLenum pname, HLint *params)
```

| Argument | Definition                                                                                                                                   |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------|
| pname    | Name of parameter (state value) to query. For a list of parameters see Table B-1, “hlGetBooleanv, hlGetIntegerv, hlGetDoublev,” on page B-2. |
| params   | Address to which to return the value of the parameter being queried.                                                                         |

**Returns:** None

**Usage:** Queries the state of the haptic renderer.

**Example:**

```
HLdouble proxyPos[3];
hlGetDoublev(HL_PROXY_POSITION, proxyPos);
HLboolean switchDown;
hlGetBooleanv(HL_BUTTON1_STATE, &switchDown);
```

**Errors:** HL\_INVALID\_ENUM if *pname* is not one of listed values.

**See also:** hlIsEnabled, hlCacheGetBooleanv, hlCacheGetDoublev

---

## hlGetError

**Description:** Returns the error code from the last API command called.

**Syntax:**

```
HLError hlGetError(void);
```

**Returns:** An HLError struct containing an HL error code and an optional device specific error code. The device specific error code is the same as the errorCode in **hdGetError()**. For an explanation of these device error codes, see Table A-15, “Device Error Codes,” on page A-13.

For a list of possible error codes the errorCode field of the returned HLError can contain, see Table B-3, “hlGetError,” on page B-6.

**Usage:** **hlGetError()** functions similarly to **hdGetError()**, i.e. it returns errors in order from most recent to least. Each call retrieves and removes one error from the error stack. Intersperse **hlGetError()** in the code to occasionally check for errors. For a list of possible error codes the errorCode field of the returned HLError can contain, see Table B-3, “hlGetError,” on page B-6.



**Example:**

```
HLerror error = hlGetError();
if (error.errorCode == HL_DEVICE_ERROR)
{
}
```

**Errors:** None

## hlGetString

**Description:** Returns a string describing the haptic renderer implementation.

**Syntax:** `const HLubyte* hlGetString(HLenum name);`

| Argument | Definition                                                                                                                    |
|----------|-------------------------------------------------------------------------------------------------------------------------------|
| name     | Haptic renderer implementation property to describe. For a list of possible names, see Table B-4, “hlGetString,” on page B-7. |

**Returns:** A static character string describing the implementation of the haptic renderer.

**Usage:** Used to determine which implementation and version of the HL library is being used. This allows for programs to take advantage of functionality in newer implementation of the library while maintaining backward compatibility.

**Example:**

```
const HLubyte* vendor = hlGetString(HL_VENDOR);
const HLubyte* version = hlGetString(HL_VERSION);
cout << "vendor= " << vendor << "version= " << version << endl;
output:
vendor=SensAble Technologies, Inc. version=1.01.23
```

**Errors:** HL\_INVALID\_ENUM if *name* is not one of the values listed.

## hlHinti, hlHintb

**Description:** Sets parameters that allow the haptic renderer to optionally perform selected optimizations.

**Syntax:** `void hlHinti(HLenum target, HLint value)`  
`void hlHintb(HLenum target, HLboolean value)`

| Argument | Definition                                                                                         |
|----------|----------------------------------------------------------------------------------------------------|
| target   | Hint property to set. For list of possible values, see Table B-5, “hlHinti, hlHintb,” on page B-7. |
| value    | Value of target property to set.                                                                   |

**Returns:** None

**Usage:** Used to allow control over the optimizations used by the haptics renderer.

**Example:**

```
hlHinti(HL_SHAPE_FEEDBACK_BUFFER_VERTICES, nVertices);
hlBeginShape(HL_SHAPE_FEEDBACK_BUFFER);
glBegin(GL_TRIANGLES);
for (int i = 0; i < nVertices; ++i)
 glVertex3f(vertices[i][0], vertices[i][1],
 vertices[i][2]);
glEnd();
hlEndShape();
```

- Errors:**
- HL\_INVALID\_ENUM if *target* is not one of the values listed.
  - HL\_INVALID\_VALUE if *value* is out of range.
  - HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlBeginShape, hlPushAttrib, hlPopAttrib

---

## hIsEnabled

**Description:** Checks if a capability is enabled or disabled.

**Syntax:** hlBoolean hIsEnabled(HLenum cap);

**Returns:** HL\_TRUE if the capability is enabled in the current rendering context, HL\_FALSE if it is disabled.

| Argument | Definition                                                                                                               |
|----------|--------------------------------------------------------------------------------------------------------------------------|
| cap      | Capability to query. For a list of possible capabilities, see Table B-9, “hlEnable, hlDisable, hIsEnabled,” on page B-9. |

**Usage:** Used to query if a particular capability feature is enabled. Capabilities include proxy resolution, haptic camera view, adaptive viewport, and gl modelview.

**Example:**

```
hlDisable(HL_PROXY_RESOLUTION);
assert(HL_FALSE == hIsEnabled(HL_PROXY_RESOLUTION));
```

- Errors:**
- HL\_INVALID\_ENUM if *cap* is not one of the values listed.
  - HL\_INVALID\_OPERATION if no haptic rendering is current.

---

# 7

---

## Cached State Accessors

---

### hlCacheGetBooleanv, hlCacheGetDoublev

**Description:** These functions allow querying of the different state values from a cached version of the state of the haptic renderer. Cached renderer states are passed into event and effect callback functions and contain the renderer state relevant for use by the callback function. The cache is important due to the multi-threaded implementation of the haptic renderer. The state may change between the time the event occurs and the time the callback is called.

**Syntax:**

```
void hlCacheGetBooleanv(HLcache* cache, HLenum pname,
 HLboolean *params)
void hlCacheGetDoublev(HLcache* cache, HLenum pname,
 HLdouble *params)
```

| Argument | Definition                                                                                                                                          |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------|
| cache    | state cache to query                                                                                                                                |
| pname    | Name of parameter (state value) to query. For a list of possible pname values, see Table B-2, “hlCacheGetBooleanv, hlCacheGetDoublev,” on page B-5. |
| params   | Address at which to return the value of the parameter being queried.                                                                                |

**Returns:** None

**Usage:** Queries the value of the state of the haptics renderer as stored in the state cache. Note that cached state is a subset of the full renderer state and therefore the possible arguments to the cached state query functions are a subset of those for the non-cached versions. The HLcache container is used by events and custom force effects. All positions, vectors and transforms accessible through **hlCacheGet\*()** are provided in world coordinates for events and workspace coordinates for custom force effects.

## 8 CACHED STATE ACCESSORS

*hlCacheGetBooleanv, hlCacheGetDoublev*

**Example:**

```
void onClickSphere(HLenum event, HLuInt object,
 HLenum thread,
 HLcache *cache, void *userdata)
{
 hlDouble proxyPos[3];
 hlCacheGetDoublev(cache, HL_PROXY_POSITION, proxyPos);
 hlBoolean switchDown;
 hlCacheGetBooleanv(cache, HL_BUTTON1_STATE,
 &switchDown);
}
```

**Errors:**

- HL\_INVALID\_ENUM if *param* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:**

hlGetBooleanv, hlGetDoublev, hlGetIntegerv, hlAddEventCallback

---

# 8

---

## Shapes

---

### hlBeginShape

**Description:** Indicates that subsequent geometry commands will be sent to the haptic renderer as part of the shape indicated until **hlEndShape()** is called. Geometric primitives may only be sent to the haptic renderer if they are specified inside an **hlBeginShape()/hlEndShape()** block. Grouping geometric primitives is important for two reasons:

- 1 Event callbacks will report the shape id of geometric primitives touched, and
- 2 Correct haptic rendering of geometric primitives that are dynamically moving is accomplished by looking at frame to frame differences based on shape id.

**Syntax:** `void hlBeginShape(HLenum type, HLuInt shape)`

| Argument | Definition                                                                                                   |
|----------|--------------------------------------------------------------------------------------------------------------|
| type     | Type of shape to specify. For a list of supported shapes types, see Table B-6, “hlBegin Shape,” on page B-8. |
| shape    | The id of shape to specify returned from an earlier call to <b>hlGenShapes()</b> .                           |

**Returns:** None

**Usage:** Used before specifying geometry and callback functions to the haptic renderer.

**Example:**

```
hlBeginShape(HL_SHAPE_FEEDBACK_BUFFER, myShapeId);
glBegin(GL_TRIANGLES);
glVertex3f(-1,-1,0);
glVertex3f(-1,1,0);
glVertex3f(1,1,0);
glVertex3f(1,-1,0);
glEnd();
hlEndShape();
```

**Errors:**

- **HL\_INVALID\_ENUM** if the *type* is not one of the values listed.
- **HL\_INVALID\_OPERATION** if not inside an **hlBeginFrame()/hlEndFrame()** block or if already inside an **hlBeginShape()/hlEndShape()** block.

**See also:** hlEndShape, hlHinti, hlHintb, hlCallback

---

## hlDeleteShapes

**Description:** Deallocates unique identifiers created by **hlGenShapes**.

**Syntax:** void hlDeleteShapes(HLuint shape, HLsizei range)

| Argument | Definition                                            |
|----------|-------------------------------------------------------|
| shape    | ID of first shape to delete                           |
| range    | Number of consecutive unique identifiers to generate. |

**Returns:** None

**Usage:** Deletes all consecutive shape identifiers in the range [shape, shape+range-1].

**Example:**

```
HLuint myShapeId = hlGenShapes(1);
...
hlDeleteShapes(myShapeId, 1);
```

**Errors:**

- **HL\_INVALID\_VALUE** if any of the identifiers to deallocate were not previously allocated by **hlGenShapes()**.
- **HL\_INVALID\_OPERATION** if no haptic rendering context is active.

**See also:** hlGenShapes, hlBeginShape, hlIsShape

---

## hlEndShape

- Description:** Completes the shape specified by the last call to **hlBeginShape()**. Geometry, materials, transforms and other state for the shape are captured and sent to the haptic renderer.
- Syntax:** `void hlEndShape()`
- Returns:** None
- Usage:** After a call to **hlBeginShape()**.
- Example:**
- ```
hlBeginShape(HL_SHAPE_FEEDBACK_BUFFER, myShapeId);
glBegin(GL_TRIANGLES);
glVertex3f(-1,-1,0);
glVertex3f(-1,1,0);
glVertex3f(1,1,0);

glEnd();
hlEndShape();
```
- Errors:** **HL_INVALID_OPERATION** if not inside an **hlBeginFrame()/hlEndFrame()** or an **hlBeginShape()/hlEndShape()** block.
- See also:** `hlBeginShape`

hlGenShapes

- Description:** For shapes, generates a unique identifier that may be used with **hlBeginShape()**.
- Syntax:** `HLuint hlGenShapes(HLsizei range)`
- | Argument | Definition |
|--------------------|---|
| <code>range</code> | Number of unique identifiers to generate. |
- Returns:** A unique integer that may be used as an identifier for a shape. If the *range* is greater than one, the return value represents the first of a series of range consecutive unique identifiers.
- Usage:** Before a call to **hlBeginShape()** to create a unique identifier for the new shape.
- Example:**
- ```
HLuint myShapeId = hlGenShapes(1);
hlBeginShape(HL_SHAPE_FEEDBACK_BUFFER, myShapeId);
...
hlEndShape();
```
- Errors:** **HL\_INVALID\_OPERATION** if no haptic rendering context is active.
- See also:** `hlBeginShape`, `hlDeleteShapes`, `hlIsShape`

---

## hlLocalFeature

- Description:** These functions specify local feature geometry to the haptic renderer.

**Syntax:**

```
void hlLocalFeature1fv(HLgeom *geom, HLenum type,
 const HLfloat *v)
void hlLocalFeature1dv(HLgeom *geom, HLenum type,
 const HLdouble *v)
void hlLocalFeature2fv(HLgeom *geom, HLenum type,
 const HLfloat *v1,
 const HLfloat *v2)
void hlLocalFeature2dv(HLgeom *geom, HLenum type,
 const HLdouble *v1,
 const HLdouble *v2)
```

| <b>Argument</b> | <b>Definition</b>                                                                                                           |
|-----------------|-----------------------------------------------------------------------------------------------------------------------------|
| geom            | Container for local features passed in as parameter to callback shape closest features callback function.                   |
| ctype           | Type of local feature to create. For a list of supported feature types, see Table B-8, “hlLocalFeature types,” on page B-9. |
| v, v1, v2       | One or two vectors, given in the local coordinates of the shape, which define the local feature.                            |

**Returns:** None

**Usage:** Called from within the closest feature callback function (HLclosestFeaturesProc) of a callback shape. Used to specify the geometry of whatever local feature of the callback shape is closest to the proxy position. That local feature is then used by the haptic renderer when either rendering the callback shape using the constraint touch model or dynamically deforming the callback shape.

In terms of threading, the haptic renderer calls the closest features callback in the collision thread and stores the local feature that is specified by that callback. The renderer then uses that local features in the servo thread to constrain the proxy and generate forces.

The example below implements a closest feature callback function for a sphere. A sphere can be represented locally as a plane tangent to a point of interest on it. So our callback function finds the closest point on the sphere to the proxy and then generates a plane tangent to the sphere at that point. This might then be used by the servo thread to constrain the proxy to the surface of the sphere.



**Example:**

```
// find the closest surface feature(s) to queryPt for sphere
// callback shape
bool closestSurfaceFeatures(const HLdouble queryPt[3],
 const HLdouble targetPt[3],
 HLgeom *geom,
 void *userdata)
{
 HapticSphere *pThis = static_cast<HapticSphere *>
 (userdata);

 // Return a plane tangent to the sphere as the closest
 // 2D local feature
 hduVector3Dd normal(queryPt);
 normal.normalize();

 hduVector3Dd point = normal * pThis->getRadius();

 hlLocalFeature2dv(geom, HL_LOCAL_FEATURE_PLANE, normal,
 point);

 return true;
}
```

**Errors:** HL\_INVALID\_ENUM if *ctype* is not one of the values listed.

**See also:** hlBeginShape, hlEndShape

## hIsShape

**Description:** Determines if an identifier is a valid shape identifier.

**Syntax:** HLboolean hIsShape(HLuint shape)

| Argument | Definition           |
|----------|----------------------|
| shape    | Identifier of shape. |

**Returns:** Returns HL\_TRUE if the shape identifier is a valid allocated value.

**Usage:** Determines if an identifier is a valid shape identifier.

**Example:**

```
HLuint myShapeId = hlGenShapes(1);
assert(hlIsShape(myShapeId));
```

**Errors:** HL\_INVALID\_OPERATION if called within an **hlBeginShape()/ hlEndShape()** block.

**See also:** hlGenShapes, hlBeginShape, hIsShape

---

## hlGetShapeBooleanv, hlGetShapeDoublev

**Description:** These functions allow querying of the state of specific shapes.

**Syntax:**

```
void hlGetShapeBooleanv(HLuint shapeId, HLenum pname,
 HLboolean *params)
void hlGetShapeDoublev(HLuint shapeId, HLenum pname,
 HLdouble *params)
```

| Argument | Definition                                                                                                                                              |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| shapeid  | Identifier of shape to query.                                                                                                                           |
| pname    | Name of parameter (state value) to query.                                                                                                               |
| params   | Address at which to return the value of the parameter being queried. For a list of supported shapes types, see Table , “Shape Parameters,” on page B-8. |

**Returns:** None

**Usage:** Queries the state of the shape with identifier *shapeid* from the haptic rendering engine. This shape must have been rendered during the last frame.

**Example:**

```
HLboolean isTouching;
hlGetShapeBooleanv(myShapeId, HL_PROXY_IS_TOUCHING,
 &isTouching);
if (isTouching)
{
 hduVector3Dd force;
 hlGetShapeDoublev(myShapeId, HL_REACTION_FORCE, force);
}
```

**Errors:**

- HL\_INVALID\_ENUM if *param* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlBeginShape, hlEndShape, hlGetBooleanv, hlGetDoublev, hlGetIntegerv

---

# 9

---

## Material and Surface Properties.

---

### hlGetMaterialfv

**Description:** Gets the current haptic material properties for shapes.

**Syntax:** `void hlGetMaterialfv(HLenum face, HLenum pname, HLfloat *param)`

| Argument | Definition                                                                                                                                 |
|----------|--------------------------------------------------------------------------------------------------------------------------------------------|
| face     | Face(s) to apply this material to. For a list of the supported face values, see Table B-12, “hlGetMaterialfv - face values,” on page B-11. |
| pname    | Material property to set. For a list of the supported values for pname, see Table B-11, “hlMaterialf - pname values,” on page B-10.        |
| param    | New value for material property.                                                                                                           |

**Returns:** None

**Usage:** Used to find the material properties that will be used for rendering shapes.

**Example:**

```
hlFloat stiffness;
hlGetMaterialfv(HL_FRONT, HL_STIFFNESS, &stiffness);
```

**Errors:**

- HL\_INVALID\_ENUM if the *face* or *pname* arguments are not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlMaterialf, hlPushAttrib, hlPopAttrib

## hlMaterialf

**Description:** Sets haptic material properties for shapes. Material properties can be set independently for front and back facing triangles of contact shapes. Only front face materials apply to constraints.

**Syntax:** `void hlMaterialf(HLenum face, HLenum pname, HLfloat param)`

| Argument | Definition                                                                                                                             |
|----------|----------------------------------------------------------------------------------------------------------------------------------------|
| face     | Face(s) to apply this material to. For a list of the supported face values, see Table B-10, “hlMaterialf - face values,” on page B-10. |
| pname    | Material property to set. For a list of the supported values for pname, see Table B-11, “hlMaterialf - pname values,” on page B-10.    |
| param    | New value for material property.                                                                                                       |

**Returns:** None

**Usage:** Used before defining shapes to set their materials.

**Example:**

```
hlMaterialf(HL_FRONT_AND_BACK, HL_STIFFNESS, 0.8);
hlMaterialf(HL_FRONT_AND_BACK, HL_DAMPING, 0.6);
hlMaterialf(HL_FRONT_AND_BACK, HL_STATIC_FRICTION, 0.5);
hlMaterialf(HL_FRONT_AND_BACK, HL_DYNAMIC_FRICTION, 0.4);
```

**Errors:**

- HL\_INVALID\_ENUM if the *face* or *pname* arguments are not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is current.
- HL\_INVALID\_VALUE if *param* is not between 0 and 1.

**See also:** hlGetMaterialfv, hlPushAttrib, hlPopAttrib

---

## hlTouchableFace

**Description:** Sets which faces of shapes will be touchable by the haptic device.

**Syntax:** `void hlTouchableFace(HLenum mode)`

| Argument | Definition                                                                                                                           |
|----------|--------------------------------------------------------------------------------------------------------------------------------------|
| mode     | Which face(s) of shapes to make touchable. For a list of mode values, see Table B-14, “hlTouchableFace - mode values,” on page B-11. |

**Returns:** None

**Usage:** Shapes may be touchable on one or both sides. Use this function to set which of those sides is touchable. The front side of feedback buffer and depth buffer shapes is defined by the winding order of the vertices as set in OpenGL; that is, triangles considered front facing by OpenGL will also be considered as front facing by HL.

When using the HL\_CONSTRAINT touch model, all shapes are always touchable from both sides, independent of the touchable face.

**Example:** `hlTouchableFace(HL_FRONT);`

**Errors:**

- HL\_INVALID\_ENUM if the *mode* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlTouchModel

---

## hlTouchModel

**Description:** Sets the touch model to specify shapes as contact shapes or constraints.

**Syntax:** `void hlTouchModel(HLenum mode)`

| Argument | Definition                                                                                                      |
|----------|-----------------------------------------------------------------------------------------------------------------|
| mode     | Contact or constraint model. For a list of supported mode values, see Table B-15, “hlTouchModel,” on page B-12. |

**Returns:** None

**Usage:** Used before specifying a shape to set whether it is a contact shape that resists penetration or whether it is a constraint that will force the haptic device to the surface of the shape.

**Example:** `hlTouchModel(HL_CONTACT);`

**Errors:**

- HL\_INVALID\_ENUM if *mode* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlTouchModelf, hlPushAttrib, hlPopAttrib

## hlTouchModelf

**Description:** Sets properties of the touch model.

**Syntax:** `void hlTouchModelf(HLenum pname, HLfloat param)`

| Argument           | Definition                                                                                                                              |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| <code>pname</code> | Touch model parameter to modify. For a list of supported values for <code>pname</code> , see Table B-16, “hlTouchModelf,” on page B-12. |
| <code>param</code> | New value for the parameter.                                                                                                            |

**Returns:** None

**Usage:** Used before specifying a shape to set the parameters used by the touch model for that shape.

**Example:** `hlTouchModelf(HL_SNAP_DISTANCE, 1.5);`

**Errors:**

- `HL_INVALID_ENUM` if *pname* is not one of the values listed.
- `HL_INVALID_OPERATION` if no haptic rendering context is current.

**See also:** `hlTouchModel`, `hlPushAttrib`, `hlPopAttrib`

---

# 10

---

## Force Effects

---

### hlDeleteEffects

**Description:** For effect, deallocates unique identifiers created by **hlGenEffects()**.

**Syntax:** `void hlDeleteEffects(HLuint effect, HLsizei range)`

| Argument | Definition                                            |
|----------|-------------------------------------------------------|
| effect   | Identifier of first effect to delete.                 |
| range    | Number of consecutive unique identifiers to generate. |

**Returns:** None

**Usage:** Deletes all consecutive effect identifiers starting in the range [effect, effect+range-1].

**Example:**

```
HLuint myEffectId = hlGenEffects(1);
...
hlDeleteEffects(myEffectId, 1);
```

**Errors:**

- **HL\_INVALID\_VALUE** if any of the *effect* identifiers to deallocate were not previously allocated by **hlGenEffects()**
- **HL\_INVALID\_OPERATION** if no haptic rendering context is active.

**See also:** `hlGenEffects`, `hlStartEffect`, `hlStopEffect`, `hlIsEffect`

---

## hlEffectd, hlEffecti, hlEffectdv, hlEffectiv

**Description:** Sets the current value of an effect property.

**Syntax:**

```
void hlEffectd (HLenum pname, HLdouble param)
void hlEffecti (HLenum pname, HLint param)
void hlEffectdv (HLenum pname, const HLdouble *params)
void hlEffectiv (HLenum pname, const HLint *params)
```

| Argument | Definition                                                                                                                                |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------|
| pname    | The name of parameter to set. For a list of possible names, see Table B-19, “hlEffectd, hlEffecti, hlEffectdv, hlEffectiv,” on page B-15. |
| params   | The new value of the property.                                                                                                            |

**Returns:** None

**Usage:** Sets the value of an effect property which will be applied to the effect generated by the next call to **hlStartEffect()** or **hlTriggerEffect()**.

**Example:**

```
hlBeginFrame();
hlEffectd(HL_EFFECT_PROPERTY_DURATION, pulseLength);
hlEffectd(HL_EFFECT_PROPERTY_GAIN, 0.4);
hlEffectd(HL_EFFECT_PROPERTY_MAGNITUDE, 0.4);
hlTriggerEffect(HL_EFFECT_FRICTION);
hlEndFrame();
```

**Errors:**

- HL\_INVALID\_ENUM if the *type* is not one of the values listed.
- HL\_INVALID\_OPERATION if not inside an **hlBeginFrame()/hlEndFrame()** block or if inside an **hlBeginShape()/hlEndShape()** block.

**See also:** hlStartEffect, hlTriggerEffect, hlStartEffect, hlEffectd, hlEffecti, hlEffectdv, hlEffectiv, hlCallback, hlPushAttrib, hlPopAttrib



---

## hlGenEffects

**Description:** Generates unique identifiers for effects that may be used with **hlStartEffect()**.

**Syntax:** `HLuint hlGenEffects(HLsizei range)`

| Argument | Definition                               |
|----------|------------------------------------------|
| range    | Number of unique identifiers to generate |

**Returns:** A unique integer that may be used as an identifier for an effect. If the range argument is greater than one, the return value represents the first of a series of range consecutive unique identifiers.

**Usage:** Before a call to **hlStartEffect()** to create a unique identifier for the new effect.

**Example:**

```
HLuintfriction = hlGenEffects(1);
hlBeginFrame();
hlEffectd(HL_EFFECT_PROPERTY_GAIN, 0.4);
hlEffectd(HL_EFFECT_PROPERTY_MAGNITUDE, 0.4);
hlStartEffect(HL_EFFECT_FRICTION, friction);
hlEndFrame();
```

**Errors:** **HL\_INVALID\_OPERATION** if no haptic rendering context is active or if inside an **hlBeginShape()/hlEndShape()** block.

**See also:** **hlStartEffect**, **hlStopEffect**, **hlDeleteEffects**, **hlIsEffect**

---

## hlGetEffectdv, hlGetEffectiv, hlGetEffectbv

**Description:** Queries the current value of an effect property.

**Syntax:**

```
void hlGetEffectdv (HLuint effect, HLenum pname,
 HLdouble *param)
void hlGetEffectiv (HLuint effect, HLenum pname,
 HLint *param)
void hlGetEffectbv (HLuint effect, HLenum pname,
 HLboolean *params)
```

| Argument | Definition                                                                                                                                    |
|----------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| effect   | Identifier of effect to query.                                                                                                                |
| pname    | Name of parameter to query. For a list of supported name values, see Table B-20, “hlGetEffectdv, hlGetEffectiv, hlGetEffectbv,” on page B-15. |
| params   | Receives the value of the property.                                                                                                           |

**Returns:** None

**Usage:** Gets the value of an effect property which will be applied to the effect generated by the next call to **hlStartEffect()** or **hlTriggerEffect()**.

**Example:**

```
hlBeginFrame();
hlEffectd(HL_EFFECT_PROPERTY_GAIN, 0.4);
hlStartEffect(myEffect, HL_EFFECT_FRICTION);
hlEndFrame();

HLdouble gain;
hlGetEffectdv(myEffect, HL_EFFECT_PROPERTY_GAIN, &gain);
assert(gain == 0.4);
```

**Errors:**

- HL\_INVALID\_ENUM if the *pname* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlStartEffect, hlTriggerEffect, hlEffectd, hlEffecti, hlEffectdv, hlEffectiv

---

## hIsEffect

**Description:** Determine if an identifier is a valid effect identifier.

**Syntax:** HLboolean hIsEffect(HLuint effect)

| Argument | Definition                           |
|----------|--------------------------------------|
| effect   | Identifier of first effect to check. |

**Returns:** None

**Usage:** Returns true if *effect* is a valid identifier that was previously returned by **hlGenEffects()**.

**Example:**

```
HLuint myEffectId = hlGenEffects(1);
...
assert(hlIsEffect(myEffectId));
```

**Errors:** HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlGenEffects

---

## hlStartEffect

**Description:** Starts an effect that will continue to run until it is terminated by a call to **hlStopEffect()**.

**Syntax:** `void hlStartEffect (HLenum type, HLuInt effect)`

| Argument | Definition                                                                                                            |
|----------|-----------------------------------------------------------------------------------------------------------------------|
| type     | Type of effect to start. For a list of supported types, see Table B-17, “hlStartEffect - effect types,” on page B-13. |
| effect   | Identifier of effect to start, generated by a call to <b>hlGenEffects()</b> .                                         |

**Returns:** None

**Usage:** Starting an effect will cause it to continue to run until **hlStopEffect()** is called to terminate it. When using **hlStartEffect()**, the duration property is ignored.

**Example:**

```
hlBeginFrame();
hlEffectd(HL_EFFECT_PROPERTY_GAIN, 0.4);
hlEffectd(HL_EFFECT_PROPERTY_MAGNITUDE, 0.4);
hlStartEffect(HL_EFFECT_FRICTION);
hlEndFrame();
```

**Errors:**

- **HL\_INVALID\_ENUM** if the *type* is not one of the values listed.
- **HL\_INVALID\_OPERATION** if not inside an **hlBeginFrame()/hlEndFrame()** block or if inside an **hlBeginShape()/hlEndShape()** block.

**See also:** `hlStopEffect`, `hlEffectd`, `hlEffecti`, `hlEffectdv`, `hlEffectiv`, `hlTriggerEffect`, `hlCallback`

## hlStopEffect

**Description:** Stops an effect that was started with **hlStartEffect()**.

**Syntax:** `void hlStopEffect (HLuint effect);`

| Argument | Definition                                                                   |
|----------|------------------------------------------------------------------------------|
| effect   | Identifier of effect to stop, generated by a call to <b>hlGenEffects()</b> . |

**Returns:** None

**Usage:** Once an effect has been started by a call **hlStartEffect()**, it will continue running until **hlStopEffect()** is called.

**Example:**

```
hlBeginFrame();
hlStopEffect(friction);
hlEndFrame();
```

**Errors:** HL\_INVALID\_OPERATION if not inside an **hlBeginFrame()/hlEndFrame()** block or if inside an **hlBeginShape()/hlEndShape()** block.

**See also:** hlStartEffect, hIEffectd, hIEffectdv, hIEffecti, hIEffectiv, hlTriggerEffect, hlCallback

---

## hlTriggerEffect

**Description:** Starts an effect which will continue to run for a specified duration.

**Syntax:** `void hlTriggerEffect (HLenum type);`

| Argument | Definition                                                                                                   |
|----------|--------------------------------------------------------------------------------------------------------------|
| type     | Type of effect to start. For a list of support value types, see Table B-18, “hlTriggerEffect,” on page B-14. |

**Returns:** None

**Usage:** Triggering an effect will cause it to continue to run for the amount of time specified by the current effect duration. Unlike effects started with **hlStartEffect()**, those started with **hlTriggerEffect()** do not need to be terminated with a call to **hlStopEffect()**. The effect will be terminated automatically when the time elapsed since the call to **hlTriggerEffect()** becomes greater than the effect duration. The effect duration will be the value specified by the last call to **hIEffectd()** with HL\_EFFECT\_PROPERTY\_DURATION.

**Example:**

```
hlBeginFrame();
hlEffectd(HL_EFFECT_PROPERTY_DURATION, pulseLength);
hlEffectd(HL_EFFECT_PROPERTY_GAIN, 0.4);
hlEffectd(HL_EFFECT_PROPERTY_MAGNITUDE, 0.4);
hlTriggerEffect(HL_EFFECT_FRICTION);
hlEndFrame();
```

**Errors:**

- `HL_INVALID_ENUM` if the *type* is not one of the values listed.
- `HL_INVALID_OPERATION` if not inside an **hlBeginFrame()/hlEndFrame()** block or if inside an **hlBeginShape()/hlEndShape()** block.

**See also:** `hlStartEffect`, `hlEffectd`, `hlEffecti`, `hlEffectdv`, `hlEffectiv`, `hlCallback`

## hlUpdateEffect

**Description:** Updates the given active effect with the current effect state.

**Syntax:** `hlUpdateEffect(HLuint effect)`

| Argument            | Definition                         |
|---------------------|------------------------------------|
| <code>effect</code> | The id of the effect to be updated |

**Returns:** None

**Usage:** **hlUpdateEffect()** is used for changing parameters of an effect that is currently active (has been started by **hlStartEffect()**). For example, the user may want to increase the force of a spring effect each time a button is pressed; **hlUpdateEffect()** allows the effect to be changed in place without the user stopping the effect, specifying new parameters, and starting it again. The effect is updated with whatever effect properties are in the current state, just as if the effect was specified via **hlStartEffect()**.

**Example:**

```
hlStartEffect(HL_EFFECT_SPRING, springEffect);
...
hlEffectd(HL_EFFECT_PROPERTY_GAIN, 0.1);
hlUpdateEffect(springEffect);
```

**Errors:** `HL_INVALID_VALUE` if effect is not an active effect.

**See also:** `hlStartEffect`, `hlStopEffect`

11 FORCE EFFECTS  
*hlUpdateEffect*

---

# 11

---

## Proxy

---

### hlProxydv

**Description:** Sets properties of the proxy.

**Syntax:** `void hlProxydv (HLenum pname, const HLdouble *params)`

| Argument           | Definition                                                                                           |
|--------------------|------------------------------------------------------------------------------------------------------|
| <code>pname</code> | Name of parameter to set. For a list of supported pnames, see Table B-25, “hlProxydv,” on page B-18. |
| <code>param</code> | Value of the property to set.                                                                        |

**Returns:** None

**Usage:** Sets properties of the proxy. The proxy is a virtual object that follows the haptic device but is constrained by geometric primitives. The force sent to the haptic device is based in part on the relative positions of the haptic device and proxy. When proxy resolution is enabled, the haptic rendering engine updates the proxy transform automatically as the haptic device moves and geometric primitives change. Users may disable automatic proxy resolution (see **hlDisable**) and set the proxy transform directly in order to use their own algorithms for proxy resolution.

**Example:**

```
hlBeginFrame();
hlDisable(HL_PROXY_RESOLUTION);
HLdouble newProxyPos[] = {3, 4, 5};
hlProxydv(HL_PROXY_POSITION, newProxyPos);
hlEndFrame();
```

**Errors:**

- `HL_INVALID_ENUM` if the *pname* is not one of the values listed.
- `HL_INVALID_OPERATION` if no haptic rendering context is active or if not within an **hlBeginFrame()/hlEndFrame()** block.

**See also:** `hlEnable`, `hlDisable`, `hlGetBooleany`, `hlGetDoublev`, `hlGetIntegerv`

12 PROXY  
*hlProxydv*



---

# 12

---

## Transforms

---

### hlLoadIdentity

**Description:** Replaces the current matrix on the top of the current matrix stack with the identity matrix.

**Syntax:** `void hlLoadIdentity(void)`

**Returns:** None

**Usage:** Clears the top of the current matrix and replaces it with the identity matrix:

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

This command applies to either the touchworkspace, viewtouch matrix or modelview depending on the current matrix mode.

**Example:**

```
hlMatrixMode(HL_TOUCHWORKSPACE);
hlPushMatrix(); // save off old touchworkspace matrix
hlLoadIdentity(); // set touchworkspace to identity
hlScaled(wsscale, wsscale, wsscale); // set scale
// render some stuff
...
hlPopMatrix(); // restore old touchworkspace matrix
```

**Errors:** `HL_INVALID_OPERATION` if no haptic rendering context is active.

**See also:** `hlMatrixMode`, `hlPushMatrix`, `hlPopMatrix`, `hlTranslated`, `hlTranslatef`, `hlRotated`, `hlRotatef`, `hlScaled`, `hlScalef`, `hlLoadMatrixd`, `hlLoadMatrixf`, `hlMultMatrixd`, `hlMultMatrixf`, `hlGetBooleany`, `hlGetDoublev`, `hlGetIntegerv`

## hlLoadMatrixd, hlLoadMatrixf

**Description:** Replaces the current matrix on the top of the current matrix stack with the 4x4 matrix specified.

**Syntax:** `void hlLoadMatrixd(const HLdouble *m)`  
`void hlLoadMatrixf(const HLfloat *m)`

| Argument       | Definition                                                                                     |
|----------------|------------------------------------------------------------------------------------------------|
| <code>m</code> | An array of 16 floating points or double precision values representing a 4x4 transform matrix. |

**Returns:** None

**Usage:** Clears the top of the current matrix and replaces it with the 4x4 matrix constructed from the values in `m` as follows:

$$\begin{pmatrix} m_0 & m_4 & m_8 & m_{12} \\ m_1 & m_5 & m_9 & m_{13} \\ m_2 & m_6 & m_{10} & m_{14} \\ m_3 & m_7 & m_{11} & m_{15} \end{pmatrix}$$

This command applies to either the touchworkspace, viewtouch matrix or modelview depending on the current matrix mode.

**Example:**

```
HLdouble myShapeXfm[16];
...
hlPushMatrix(); // save off old matrix
hlLoadMatrixd(myShapeXfm); // set xfm
// render some stuff
...
hlPopMatrix(); // restore old matrix
```

**Errors:** `HL_INVALID_OPERATION` if no haptic rendering context is active.

**See also:** `hlMatrixMode`, `hlPushMatrix`, `hlPopMatrix`, `hlTranslated`, `hlTranslatf`, `hlRotated`, `hlRotatf`, `hlScaled`, `hlScalef`, `hlLoadIdentity`, `hlMultMatrixd`, `hlMultMatrixf`, `hlGetBooleany`, `hlGetDoublev`, `hlGetIntegerv`

---

## hlMultMatrixd, hlMultMatrixf

**Description:** Multiplies the current matrix on the top of the current matrix stack with the 4x4 matrix specified.

**Syntax:**

```
void hlMultMatrixd(const Hldouble *m)
void hlMultMatrixf(const HLfloat *m)
```

| Argument | Definition                                                                                     |
|----------|------------------------------------------------------------------------------------------------|
| m        | An array of 16 floating points or double precision values representing a 4x4 transform matrix. |

**Returns:** None

**Usage:** Replaces the top of the current matrix stack with the product of the top of the stack and the matrix constructed from the values in m as follows:

$$\begin{pmatrix} m_0 & m_4 & m_8 & m_{12} \\ m_1 & m_5 & m_9 & m_{13} \\ m_2 & m_6 & m_{10} & m_{14} \\ m_3 & m_7 & m_{11} & m_{15} \end{pmatrix}$$

This command applies to either the touchworkspace, viewtouch matrix or modelview depending on the current matrix mode.

**Example:**

```
Hldouble myShapeXfm[16];
...
hlPushMatrix(); // save off old matrix
hlMultMatrixd(myShapeXfm); // set xfm
// render some stuff
...
hlPopMatrix(); // restore old matrix
```

**Errors:** HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlMatrixMode, hlPushMatrix, hlPopMatrix, hlTranslated, hlTranslatf, hlRotated, hlRotatf, hlScaled, hlScalef, hlLoadIdentity, hlLoadMatrixd, hlLoadMatrixf, hlGetBooleany, hlGetDoublev, hlGetIntegerv

---

## hlMatrixMode

**Description:** Sets which matrix stack is the target for future calls to matrix manipulation commands.

**Syntax:** `void hlMatrixMode(HLenum mode);`

| Argument | Definition                                                                                                                                     |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------|
| mode     | Which matrix stack to apply matrix manipulation commands to. See Table B-26, “hlMatrix - mode values,” on page B-19 for a list of valid modes. |

**Returns:** None

**Usage:** The HLAPI maintains two transforms that, when multiplied together, determine the mapping from the local coordinate system of the haptic device (workspace coordinates) to graphical view coordinates. The first transform maps from touch coordinates to workspace coordinates and the second maps from view coordinates to touch coordinates. The API maintains a stack of matrices for each of these of two transforms where the top of the stack represents the current matrix to use for the transform. HLAPI also maintains an optional modelview matrix stack. The modelview maps from model coordinates to view coordinates. By default, HLAPI ignores this stack and instead uses the current OpenGL modelview matrix. This allows easier reuse of OpenGL code by applying OpenGL transformations to geometry for haptic rendering. In some cases you may not want to use the OpenGL modelview matrix (for example, if you have no OpenGL rendering context.) In this case you can disable the use of the OpenGL modelview matrix by calling **hlDisable(HL\_USE\_GL\_MODELVIEW)** and HLAPI will use its own modelview matrix instead. All matrix manipulation commands target the top matrix on one of these two stacks. Setting the matrix mode controls which of the three stacks is targeted.

**Example:**

```
hlMatrixMode(HL_TOUCHWORKSPACE);
hlPushMatrix(); // save off old touchworkspace matrix
hlLoadIdentity(); // set touchworkspace to identity
hlScaled(wsscale, wsscale, wsscale); // set scale
// render some stuff
...
hlPopMatrix(); // restore old touchworkspace matrix
```

**Errors:**

- HL\_INVALID\_ENUM if the *mode* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlPushMatrix, hlPopMatrix, hlTranslatef, hlTranslated, hlRotatef, hlRotated, hlScalef, hlScaled, hlWorkspace, hlLoadMatrixd, hlLoadMatrixf, hlMultMatrixd, hlMultMatrixf, hlGetBooleany, hlGetDoublev, hlGetIntegerv

---

## hlOrtho

**Description:** Sets up the haptic view volume which determines how the workspace of the haptic device will be mapped into the graphical view volume.

**Syntax:**

```
void hlOrtho (HLdouble left, HLdouble right,
 HLdouble bottom, HLdouble top,
 HLdouble zNear, HLdouble zFar);
```

| Argument    | Definition                                                                  |
|-------------|-----------------------------------------------------------------------------|
| left, right | The coordinates of the left and right boundaries of the haptic view volume  |
| top, bottom | The coordinates of the top and bottom boundaries of the haptic view volume. |
| zNear, zFar | The coordinates of the front and back boundaries of the haptic view volume. |

**Returns:** None

**Usage:** The **hlOrtho()** function is used in conjunction with **hlWorkspace()** to determine the mapping between the physical workspace of the haptic device and the graphical view. **hlOrtho()** defines an orthogonal view volume (that is an axis oriented bounding box) in the graphical view coordinate system. **hlWorkspace()** defines a corresponding box in the physical coordinates of the haptic device. The haptic rendering engine uses these to determine a transformation between the two coordinate spaces. Specifically, the API creates a transform consisting of a uniform or non-uniform scale about the center of the workspace box and a translation. The product of this transform and the top of the matrix stack replaces the current top of the matrix stack. This function is generally used with the **HL\_TOUCHWORKSPACE** matrix mode.

**Example:**

```
hlMatrixMode(HL_TOUCHWORKSPACE);

// clear the matrix stack
hlLoadIdentity();

// specify the boundaries for the workspace of the haptic
// device in millimeters in the cordiantes of the haptic
// device the haptics engine will map the view volume to
// this workspace
hlWorkspace (-80, -80, -70, 80, 80, 20);
// specify the haptic view volume
hlOrtho (0.0, 1.0, 0.0, 1.0, -1.0, 1.0);
```

**Errors:** **HL\_INVALID\_OPERATION** if no haptic rendering context is active.

**See also:** **hlWorkspace**, **hlMatrixMode**

## hlPushAttrib, hlPopAttrib

**Description:** **hlPushAttrib()** pushes a set of attributes onto the top of the current attribute matrix stack. **hlPopAttrib()** removes the top of the current attribute stack.

**Syntax:**

```
void hlPushAttrib(HLbitfield mask)
void hlPopAttrib()
```

| Argument | Definition                                                                                                              |
|----------|-------------------------------------------------------------------------------------------------------------------------|
| mask     | The type of attributes to push. See Table B-27, “hlPushAttrib, hlPopAttrib,” on page B-19 for a list of attribute bits. |

**Returns:** None

**Usage:** **hlPush()/PopAttrib()** allows the user to save and restore rendering state attributes. It works similarly to **hlPush()/PopMatrix()**, except that it allows the user to selectively push attributes onto the stack.

**Example:**

```
hlPushAttrib(HL_HINT_BIT | HL_TRANSFORM_BIT);
```

**Errors:** HL\_INVALID\_VALUE if mask is not an attribute bit or set of attribute bits.

**See also:** hlPushMatrix, hlPopMatrix

---

## hlPushMatrix, hlPopMatrix

**Description:** **hlPushMatrix()** pushes a new matrix onto the top of the current matrix stack. **hlPopMatrix()** removes the top of the current matrix stack.

**Syntax:**

```
void hlPushMatrix()
void hlPopMatrix()
```

**Returns:** None

**Usage:** The HLAPI maintains matrix stacks for the viewtouch matrix, the touchworkspace matrix, and optionally for the modelview matrix. **hlPushMatrix()** and **hlPopMatrix()** allow these matrix stacks to be changed temporarily and then restored. **hlPushMatrix()** pushes a new matrix onto the top of the current matrix stack. The new matrix is initially a duplicate of the existing matrix on the top of the stack. **hlPopMatrix()** removes the matrix on the top of the stack, leaving the old top of the stack as the current matrix.

This command applies to either the touchworkspace, viewtouch matrix, or modelview depending on the current matrix mode.

**Example:**

```
hlPushMatrix(); // save off old matrix
hlTranslate(0, 20, 0); // move geometry up 20
// draw some stuff
hlPopMatrix(); // restore old matrix
```

**Errors:**

- HL\_INVALID\_OPERATION if no haptic rendering context is active.

- `HL_STACK_OVERFLOW` if `hlPushMatrix()` is called when the matrix stack is already full.
- `HL_STACK_UNDERFLOW` if `hlPopMatrix()` is called when the matrix stack is only one deep.

**See also:** `hlMatrixMode`, `hlTranslated`, `hlTranslatef`, `hlRotated`, `hlRotatef`, `hlScaled`, `hlScalef`, `hlLoadIdentity`, `hlLoadMatrixd`, `hlLoadMatrixf`, `hlMultMatrixd`, `hlMultMatrixf`, `hlGetBooleany`, `hlGetDoublev`, `hlGetIntegerv`, `hlPushAttrib`, `hlPopAttrib`

## hlRotatef, hlRotated

**Description:** Multiplies the current matrix on the top of the current matrix stack by a 4x4 rotation matrix.

**Syntax:**

```
void hlRotated (HLdouble angle, HLdouble x, HLdouble y,
 HLdouble z)
void hlRotatef (HLfloat angle, HLfloat x,
 HLfloat y,HLfloatz)
```

| Argument | Definition                                                           |
|----------|----------------------------------------------------------------------|
| angle    | Angle, in degrees, to rotate.                                        |
| x, y, z  | Coordinates of a vector representing the axis about which to rotate. |

**Returns:** None

**Usage:** Creates a 4x4 rotation matrix that represents a rotation of angle degrees about the given axis. Replaces the top of the current matrix stack with the product of the top of the matrix stack and the rotation matrix. The rotation matrix created is of the form:

$$\begin{pmatrix} x^2 + \cos(\text{angle})(1 - x^2) & xy[1 - \cos(\text{angle})] - z \sin(\text{angle}) & zx[1 - \cos(\text{angle})] + y \sin(\text{angle}) & 0 \\ xy[1 - \cos(\text{angle})] + z \sin(\text{angle}) & y^2 + \cos(\text{angle})(1 - y^2) & yz[1 - \cos(\text{angle})] - x \sin(\text{angle}) & 0 \\ zx[1 - \cos(\text{angle})] - y \sin(\text{angle}) & yz[1 - \cos(\text{angle})] + x \sin(\text{angle}) & z^2 + \cos(\text{angle})(1 - z^2) & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

This command applies to either the touchworkspace, viewtouch matrix, or modelview matrix depending on the current matrix mode.

**Example:**

```
hlPushMatrix(); // save off old matrix
hlRotate(45, 0, 0, 1); // rotate 45 degrees about z axis
// draw some stuff
hlPopMatrix(); // restore old matrix
```

**Errors:** `HL_INVALID_OPERATION` if no haptic rendering context is active.

**See also:** `hlMatrixMode`, `hlPushMatrix`, `hlPopMatrix`, `hlTranslated`, `hlTranslatef`, `hlScaled`, `hlScalef`, `hlLoadIdentity`, `hlLoadMatrixd`, `hlLoadMatrixf`, `hlMultMatrixd`, `hlMultMatrixf`, `hlGetBooleany`, `hlGetDoublev`, `hlGetIntegerv`

## hlScalef, hlScaled

**Description:** Multiplies the current matrix on the top of the current matrix stack by a 4x4 scale matrix.

**Syntax:**

```
void hlScaled(HLdouble x, HLdouble y, HLdouble z);
void hlScalef(HLfloat x, HLfloat y, HLfloat z);
```

| Argument | Definition                                            |
|----------|-------------------------------------------------------|
| x, y, z  | Scale factors about the x, y and z axes respectively. |

**Returns:** None

**Usage:** Creates a 4x4 scale matrix that scales about the three coordinate axes. Replaces the top of the current matrix stack with the product of the top of the matrix stack and the scale matrix. The scale matrix created is of the form:

$$\begin{pmatrix} x & 0 & 0 & 0 \\ 0 & y & 0 & 0 \\ 0 & 0 & z & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

This command applies to either the touchworkspace, viewtouch matrix, or modelview matrix depending on the current matrix mode.

**Example:**

```
hlPushMatrix(); // save off old matrix
hlScale(1, 2, 1); // scale 2x along y axis
// draw some stuff
hlPopMatrix(); // restore old matrix
```

**Errors:** HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlMatrixMode, hlPushMatrix, hlPopMatrix, hlTranslated, hlTranslatex, hlRotated, hlRotatef, hlLoadIdentity, hlLoadMatrixd, hlLoadMatrixf, hlMultMatrixd, hlMultMatrixf, hlGetBooleany, hlGetDoublev, hlGetIntegerv



---

## hlTranslatef, hlTranslated

**Description:** Multiplies the current matrix on the top of the current matrix stack by a 4x4 translation matrix.

**Syntax:**

```
void hlTranslated (HLdouble x, HLdouble y, HLdouble z)
void hlTranslatef (HLfloat x, HLfloat y, HLfloat z)
```

| Argument | Definition                         |
|----------|------------------------------------|
| x, y, z  | Coordinates of translation vector. |

**Returns:** None

**Usage:** Creates a 4x4 translation matrix based on the vector (x, y, z) and replaces the top of the current matrix stack with the product of the top of the matrix stack and the translation matrix. The translation matrix created is of the form:

$$\begin{pmatrix} 1 & 0 & 0 & x \\ 0 & 1 & 0 & y \\ 0 & 0 & 1 & z \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

This command applies to either the touchworkspace, viewtouch matrix, or modelview matrix depending on the current matrix mode.

**Example:**

```
hlPushMatrix(); // save off old matrix
hlTranslate(0, 20, 0); // move geometry up 20
// draw some stuff
hlPopMatrix(); // restore old matrix
```

**Errors:** HL\_INVALID\_OPERATION if no haptic rendering context is active.

**See also:** hlMatrixMode, hlPushMatrix, hlPopMatrix, hlRotated, hlRotatef, hlScaled, hlScalef, hlLoadIdentity, hlLoadMatrixd, hlLoadMatrixf, hlMultMatrixd, hlMultMatrixf, hlGetBooleanv, hlGetDoublev, hlGetIntegerv

## hlWorkspace

**Description:** Defines the extents of the workspace of the haptic device that will be used for mapping between the graphics coordinate system and the physical units of the haptic device.

**Syntax:** `void hlWorkspace (HLdouble left, HLdouble bottom, HLdouble back, HLdouble right, HLdouble top, HLdouble front);`

| Argument    | Definition                                                                       |
|-------------|----------------------------------------------------------------------------------|
| left, right | The coordinates of the left and right boundaries of the haptic device workspace. |
| top, bottom | The coordinates of the top and bottom boundaries of the haptic view volume.      |
| front, back | The coordinates of the front and back boundaries of the haptic view volume.      |

**Returns:** None

**Usage:** The **hlWorkspace()** function is used in conjunction with **hlOrtho()** to determine the mapping between the physical workspace of the haptic device and the graphical view. **hlOrtho()** defines an orthogonal view volume (that is, an axis oriented bounding box) in the graphical view coordinate system. **hlWorkspace()** defines a corresponding box in the physical coordinates of the haptic device. The haptic rendering engine uses these to determine a transformation between the two coordinate spaces. Specifically, the API creates a transform consisting of a uniform or non-uniform scale about the center of the workspace box and a translation. The product of this transform and the top of the matrix stack replaces the current top of the matrix stack. This function is generally used with the **HL\_TOUCHWORKSPACE** matrix mode.

**Example:**

```
hlMatrixMode(HL_TOUCHWORKSPACE);

// clear the matrix stack
hlLoadIdentity();

// specify the boundaries for the workspace of the haptic
// device in millimeters in the coordinates of the haptic
// device the haptics engine will map the view volume to
// this workspace
hlWorkspace (-80, -80, -70, 80, 80, 20);

// specify the haptic view volume
hlOrtho (0.0, 1.0, 0.0, 1.0, -1.0, 1.0);
```

**Errors:** **HL\_INVALID\_OPERATION** if no haptic rendering context is active.

**See also:** **hlOrtho**, **hlMatrixMode**

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## Callbacks

---

### hlCallback

**Description:** Sets a user callback function.

**Syntax:** `void hlCallback (HLenum type, HLcallbackProc fn, void *userdata)`

| Argument | Definition                                                                                                |
|----------|-----------------------------------------------------------------------------------------------------------|
| type     | Name of callback to set. For a list of supported type values, see Table B-21, “hlCallback,” on page B-16. |
| fn       | Pointer to callback function.                                                                             |
| userdata | Pointer to client specific data that will be passed to the callback function.                             |

**Returns:** None

**Usage:** Used to set callback functions for custom shapes and custom effect types.

**Example:**

```
hlBeginShape(HL_SHAPE_CALLBACK, myshape);
hlCallback(HL_SHAPE_INTERSECT_LS, HLcallbackProc)
 &intersectSurface, (void*) &myShapeData);
hlCallback(HL_SHAPE_CLOSEST_POINT, (HLcallbackProc)
 &closestPointSurface, (void*) &myShapeData);
hlEndShape();
```

**Errors:**

- HL\_INVALID\_ENUM if *type* is not one of the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlBeginShape

14 CALLBACKS  
*hlCallback*

---

# 14

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## Events

---

### hlAddEventCallback

**Description:** Adds a user defined event handling function to the list of callback functions for an event.

**Syntax:**

```
void hlAddEventCallback (HLenum event, HLuInt shapeId,
 HLenum thread, HLeventProc fn,
 void *userdata)
```

| Argument | Definition                                                                                                                                                                                                              |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| event    | Event to which to subscribe. For a list of supported event values, see Table B-22, “hlAddEventCallback, hlRemoveEventCallBack - event values;” on page B-17.                                                            |
| shapeId  | Identifier of shape. Callback will only be called if the event occurs on the shape with this identifier unless this argument is set HL_OBJECT_ANY in which case the callback will be called independent of any objects. |
| thread   | Thread to have callback function called in. For a list of support thread values, see Table B-23, “hlAddEventCallback, hlRemoveEventCallback - thread values;” on page B-18.                                             |
| fn       | Pointer to callback function.                                                                                                                                                                                           |
| userdata | Pointer to client specific data that will be passed to the callback function.                                                                                                                                           |

**Returns:** None

**Usage:** Event callbacks are used to inform programs about occurrences in the haptic renderer such as an object being touched.

**Example:**

```
void HLCALLBACK onClickSphere(HLenum event, HLuInt object,
 HLenum thread,
 HLcache *cache,
 void *userdata)
{
 // handle event
}

hlAddEventCallback(HL_EVENT_1BUTTONDOWN, mySphereId,
 HL_CLIENT_THREAD, &onClickSphere,
 (void*) &mydata);
```

- Errors:**
- HL\_INVALID\_ENUM if *event* and *thread* are not among the values listed.
  - HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlRemoveEventCallback, hlEventd, hlCheckEvents

---

## hlCheckEvents

**Description:** Calls callback functions for all events that are subscribed to and that have occurred since the last call to **hlCheckEvents()**.

**Syntax:** void hlCheckEvents()

**Returns:** None

**Usage:** Should be called on a regular basis in the client thread. This is often called as part of the main rendering loop or main event loop. This function checks if any subscribed events have been triggered since the last call to **hlCheckEvents()**. If any events have been triggered, then event callbacks for these events will be called synchronously before the call to **hlCheckEvents()** returns. This only applies to event callbacks in the client thread (HL\_THREAD\_CLIENT), collision thread events will be called from within the collision thread, outside of call to the **hlCheckEvents()**.

**hlCheckEvents()** can be called outside of a begin/endFrame pair. It can be called in place of a begin/end frame to update just device and event state. For example, if the user is feeling a static scene and only needs to have updated device state information periodically, he can forego calling **hlBegin()/EndFrame()** and instead just call **hlCheckEvents()** periodically.

**Example:**

```

void HLCALLBACK onMotion(HLenum event, HLuInt object,
 HLenum thread, HLcache *cache,
 void *userdata)
{
 hlBeginFrame();
 drawScene();
 hlEndFrame();
}

void setup()
{
 hlAddEventCallback(HL_EVENT_MOTION, HL_OBJECT_ANY,
 HL_CLIENT_THREAD, &onMotion, NULL);
}

void onIdle()
{
 hlCheckEvents();
}

```

**Errors:** HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlAddEventCallback, hlRemoveEventCallback, hlEventd

## hlEventd

**Description:** Sets parameters that influence how and when event callbacks are called.

**Syntax:** void hlEventd(HLenum pname, HLdouble param)

| Argument | Definition                                                                                                               |
|----------|--------------------------------------------------------------------------------------------------------------------------|
| pname    | Name of event parameter to set. For a list of pname parameters, see Table B-24, “hlEventd - pname values,” on page B-18. |
| param    | Value of parameter to set.                                                                                               |

**Returns:** None

**Usage:** Used at program startup to tailor the event management of the haptic renderer to the specific application.

**Example:** hlEventd(HL\_EVENT\_MOTION\_LINEAR\_TOLERANCE, 10);

**Errors:**

- HL\_INVALID\_ENUM if *pname* is not one of the values listed.
- HL\_INVALID\_VALUE if *param* value is out of range.
- HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlAddEventCallback; hlPushAttrib, hlPopAttrib

## hlRemoveEventCallback

**Description:** Removes an existing user defined event handling function from the list of callback functions for an event.

**Syntax:** `void hlRemoveEventCallback (HLenum event, HLuInt shapeId, HLenum thread, HLeventProc fn)`

| Argument | Definition                                                                                                                                                                                                                                |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| event    | Subscribed event. For a list of event parameters, see Table B-22, “hlAddEventCallback, hlRemoveEventCallBack - event values:,” on page B-17.                                                                                              |
| shapeId  | Identifier of shape. Callback will only be called if the event occurs on the shape with this identifier unless this argument is set: HL_OBJECT_ANY. In which case the callback will be called regardless of what object is being touched. |
| thread   | Thread in which to have callback function called. For a list of thread parameters, see Table B-23, “hlAddEventCallback, hlRemoveEventCallback - thread values,” on page B-18.                                                             |
| fn       | Pointer to callback function.                                                                                                                                                                                                             |

**Returns:** None

**Usage:** Removes any event callback that was added to list of subscribed events with a call to **hlAddEventCallback()** with the same *event*, *thread*, *shapeId* and *fn* pointer.

**Example:**

```
void HLCALLBACK onClickSphere(HLenum event, HLuInt object,
 HLenum thread, HLCache *cache,
 void *userdata)
{
 // handle event
}

hlAddEventCallback(HL_EVENT_1BUTTONDOWN, mySphereId,
 HL_CLIENT_THREAD, &onClickSphere,
 (void*) &mydata);
hlRemoveCallback(HL_EVENT_1BUTTONDOWN, mySphereId,
 HL_CLIENT_THREAD, &onClickSphere);
```

**Errors:**

- HL\_INVALID\_ENUM if *event* and *thread* are not among the values listed.
- HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlAddEventCallback, hlCheckEvents, hlEventd



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## Calibration

---

### hlUpdateCalibration

**Description:** Causes the haptic device to recalibrate.

**Syntax:** `void hlUpdateCalibration(void)`

**Returns:** None

**Usage:** Calibration of the haptic device is a two-stage process. First, new calibration data must be found. How this is done depends on the device hardware.

- For the PHANTOM Omni, new calibration data is found when the stylus is inserted into the inkwell.
- For the PHANTOM Desktop, calibration data is found as the device is moved about the extents of the workspace.

A program may subscribe to the `HL_EVENT_CALIBRATION_UPDATE` event to be notified when valid calibration data has been found. It may also subscribe to the `HL_EVENT_CALIBRATION_INPUT` event when to be notified when the device requires user input (such as inserting the stylus into the inkwell) in order to obtain valid data.

Once valid calibration has been found, next **hlUpdateCalibration()** is called to flush that data to the haptic device. Note that the change in calibration may cause a large discontinuity in the positions reported by the device. For this reason, **hlUpdateCalibration()** should not be called while the user is in the middle of an operation that relies on continuity of reported device positions (for example, drawing or manipulating an object). For a list of calibration event types see Table B-28, “Calibration Event Types,” on page B - 20.

**Example:**

```
void HLCALLBACK calibrationCallback(HLenum event, HLuint object,
 HLenum thread, HLcache *cache,
 void *userdata)
{
 if (event == HL_EVENT_CALIBRATION_UPDATE)
 {
 std::cout << "Device requires calibration update..." << std::endl;
 hlUpdateCalibration();
 }
 else if (event == HL_EVENT_CALIBRATION_INPUT)
 {
 std::cout << "Device requires calibration.input..." << std::endl;
 }
}

...

hlAddEventCallback(HL_EVENT_CALIBRATION_UPDATE, HL_OBJECT_ANY,
 HL_CLIENT_THREAD, &calibrationCallback, NULL);
hlAddEventCallback(HL_EVENT_CALIBRATION_INPUT, HL_OBJECT_ANY,
 HL_CLIENT_THREAD, &calibrationCallback, NULL);
```

- Errors:**
- HL\_INVALID\_ENUM if *pname* is not one of the values listed.
  - HL\_INVALID\_VALUE if value is out of range.
  - HL\_INVALID\_OPERATION if no haptic rendering context is current.

**See also:** hlAddEventCallback

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# 16

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## HLAPI Deployment

---

### hlDeploymentLicense

**Description:** Activates the deployment license issued to the application developer. Once the deployment license has been validated, it will remain active until the application is exited. It is not an error to call this more than once in an application session.

**Syntax:** `HLboolean hlDeploymentLicense (const char* vendorName, const char* applicationName, const char* password)`

| Argument        | Definition                                                     |
|-----------------|----------------------------------------------------------------|
| vendor          | The name of the organization to which the license is issued.   |
| applicationName | The name of the application the license is tied to.            |
| password        | The license string which authenticates the deployment license. |

**Returns:** Non-zero if the validation succeeded, zero if the validation failed.

**Usage:** Needs to be executed before **hlCreateContext** to operate correctly. **hlCreateContext** will fail if the deployment license is not valid. Note that if a developers license is present, **hlCreateContext** will succeed.

**Example:**

```
HLboolean bValid = hlDeploymentLicense ("Haptic Co.",
 "Haptic Application", 6A12...);
```



# Haptic Device API Parameters

The following pages contain tables that list the names of the HDAPI parameters. For each parameter the table lists a description and what types and how many values are used by each parameter name. The developer is responsible for supplying the correct number of parameters for the particular parameter name. Not all parameter names support every type.

The parameters are grouped as follows:

| <b>Topic</b>          | <b>Page</b> |
|-----------------------|-------------|
| Get Parameters        | A-2         |
| Set Parameters        | A-8         |
| Capability Parameters | A-11        |
| Codes                 | A-12        |

## Get Parameters

**Table A-1: hdGet Parameters**

| Parameter Name              | Description                                                                                                                                                                                                      | Number of Arguments | Allowed Types        | Units |
|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|-------|
| HD_CURRENT_BUTTONS          | Get the button state. Individual button values can be retrieved by doing bitwise & with HD_DEVICE_BUTTON_N (N=1,2,3, or 4).                                                                                      | 1                   | HDint                |       |
| HD_CURRENT_SAFETY_SWITCH    | Get whether the safety switch, if one exists, is active. For example, the PHANTOM Desktop's safety switch is true if the conductive portion of the stylus is being held.                                         | 1                   | HDboolean            |       |
| HD_CURRENT_INKWELL_SWITCH   | Get whether the inkwell switch, if one exists is active.                                                                                                                                                         | 1                   | HDboolean            |       |
| HD_CURRENT_ENCODER_VALUES   | Get the raw encoder values.                                                                                                                                                                                      | 6                   | HDlong               |       |
| HD_CURRENT_POSITION         | Get the current position of the device facing the device base. Right is + x, up is +y, toward user is +z.                                                                                                        | 3                   | HDdouble,<br>HDfloat | mm    |
| HD_CURRENT_VELOCITY         | Get the current velocity of the device. Note: This value is smoothed to reduce high frequency jitter.                                                                                                            | 3                   | HDdouble,<br>HDfloat | mm/s  |
| HD_CURRENT_TRANSFORM        | Get the column-major transform of the device end-effector.                                                                                                                                                       | 16                  | HDdouble,<br>HDfloat |       |
| HD_CURRENT_ANGULAR_VELOCITY | Gets the angular velocity of the device gimbal.                                                                                                                                                                  | 3                   | HDdouble,<br>HDfloat | rad/s |
| HD_CURRENT_JOINT_ANGLES     | Get the joint angles of the device. These are joint angles used for computing the kinematics of the armature relative to the base frame of the device. For PHANTOM devices: Turret Left +, Thigh Up +, Shin Up + | 3                   | HDdouble,<br>HDfloat | rad   |
| HD_CURRENT_GIMBAL_ANGLES    | Get the angles of the device gimbal. For PHANTOM devices: From Neutral position Right is +, Up is -, CW is +                                                                                                     | 3                   | HDdouble,<br>HDfloat | rad   |

**Table A-1: hdGet Parameters**

|                        |                                                                                             |   |                     |  |
|------------------------|---------------------------------------------------------------------------------------------|---|---------------------|--|
| HD_USER_STATUS_LIGHT   | Get the user setting of the LED status light. See hdDefine.h for constant settings.         | 1 | HDint               |  |
| HD_CURRENT_PINCH_VALUE | Get the current normalized pinch encoder value ( <i>NEW for v2.x Beta - Windows only</i> ). | 1 | HDdouble<br>HDfloat |  |
| HD_LAST_PINCH_VALUE    | Get the last normalized pinch encoder value ( <i>NEW for v2.x Beta - Windows only</i> ).    | 1 | HDdouble<br>HDfloat |  |

**Table A-2: Get Forces Parameters**

| Parameter Name              | Description                                                                                                                                                                                                          | Number of Arguments | Allowed Types        | Units                           |
|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|---------------------------------|
| HD_CURRENT_FORCE            | Get the current force, i.e. the force that the user is commanding to the device during the frame in which this is called. Returns 0 if no force has been commanded yet in the frame.                                 | 3                   | HDfloat,<br>HDdouble | N                               |
| HD_CURRENT_TORQUE           | Get the current torque, i.e. the torque that the user is commanding to the device during the frame in which this is called. Returns 0 if no torque has been commanded yet in the frame.                              | 3                   | HDfloat,<br>HDdouble | mNm                             |
| HD_CURRENT_MOTOR_DAC_VALUES | Get the current motor DAC, i.e. the motor value that the user is commanding to the device during the frame in which this is called. Returns 0 if no DAC has been commanded yet in the frame.                         | 3 or 6              | HDlong               | Inclusive range [-32767, 32766] |
| HD_CURRENT_JOINT_TORQUE     | Get the current joint torque, i.e. the torque the user is commanding to the first 3 joints of the device during the frame in which this is called. Returns 0 if no joint torque has been commanded yet in the frame. | 3                   | HDfloat,<br>HDdouble | mNm                             |
| HD_CURRENT_GIMBAL_TORQUE    | Get the current gimbal torque, i.e. the gimbal torque the user is commanding to the device during the frame in which this is called. Returns 0 if no gimbal torque has been commanded yet in the frame.              | 3                   | HDfloat,<br>HDdouble | mNm                             |

**Table A-3: Get Identification Parameters**

| Parameter Name                 | Description                                                                                                                                                                                                                                                    | Number of Arguments | Allowed Types        | Units |
|--------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|-------|
| HD_FIRMWARE_REVISION           | Get the firmware revision.                                                                                                                                                                                                                                     | 1                   | HDdouble             |       |
| HD_VERSION                     | Get the HDAPI software version, in the form of major.minor.build. This is taken from the HD_VERSION_ definitions.                                                                                                                                              | 1                   | HDstring             |       |
| HD_DEVICE_MODEL_TYPE           | Get a readable string of the device model type                                                                                                                                                                                                                 | 1                   | HDstring             |       |
| HD_DEVICE_DRIVER_VERSION       | Get a readable string of the driver version.                                                                                                                                                                                                                   | 1                   | HDstring             |       |
| HD_DEVICE_VENDOR               | Get a readable string of the device vendor.                                                                                                                                                                                                                    | 1                   | HDstring             |       |
| HD_DEVICE_SERIAL_NUMBER        | Gets a readable string of the device serial number.                                                                                                                                                                                                            | 1                   | HDstring             |       |
| HD_MAX_WORKSPACE_DIMENSIONS    | Get the maximum workspace dimensions of the device, i.e. the maximum mechanical limits of the device, as (minX, minY, minZ, maxX, maxY, maxZ)                                                                                                                  | 6                   | HDfloat,<br>HDdouble | mm    |
| HD_USABLE_WORKSPACE_DIMENSIONS | Get the usable workspace dimensions of the device, i.e. the practical limits for the device, as (minX, minY, minZ, maxX, maxY, maxZ). It is guaranteed that forces can be reliably rendered within the usable workspace dimensions.                            | 6                   | HDfloat,<br>HDdouble | mm    |
| HD_TABLETOP_OFFSET             | Get the mechanical offset of the device end-effector in Y from the table top.                                                                                                                                                                                  | 1                   | HDfloat              | mm    |
| HD_INPUT_DOF                   | Get the number of input degrees of freedom. (i.e. the number of independent position variables needed to fully specify the end-effector location for PHANTOM device) 3DOF input means xyz translational sensing-only. 6DOF means 3 translation and 3 rotation. | 1                   | HDint                |       |



**Table A-3: Get Identification Parameters**

|                      |                                                                                                                                                                                                                                         |   |       |  |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|-------|--|
| HD_OUTPUT_DOF        | Get the number of output degrees of freedom, i.e. the number of independent actuation variable. For PHANTOM devices 3DOF means XYZ linear force output whereas 6DOF means xyz linear forces and roll, pitch, yaw, torques about gimbal. | 1 | HDint |  |
| HD_CALIBRATION_STYLE | The style(s) of calibration supported by the device. Can be one or more bitwise of the following HD_CALIBRATION_AUTO, HD_CALIBRATION_ENCODER_RESET, or HD_CALIBRATION_INKWELL                                                           | 1 | HDint |  |

**Table A-4: Get Last Values Parameters**

| Parameter Name           | Description                                                                                                                                                                                                          | Number of Arguments | Allowed Types     | Units |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------|-------|
| HD_LAST_BUTTONS          | Get last frame's button state. Individual button values can be retrieved by doing bitwise & with HD_DEVICE_BUTTON_N (N=1,2,3, or 4).                                                                                 | 1                   | HDint             |       |
| HD_LAST_SAFETY_SWITCH    | Get last frame's safety switch active status.                                                                                                                                                                        | 1                   | HDboolean         |       |
| HD_LAST_INKWELL_SWITCH   | Get last frame's inkwell switch active status.                                                                                                                                                                       | 1                   | HDboolean         |       |
| HD_LAST_ENCODER_VALUES   | Get last frame's raw encoder values.                                                                                                                                                                                 | 6                   | HDlong            |       |
| HD_LAST_POSITION         | Get the last position of the device facing the device base. Right is + x, up is +y, toward user is +z.                                                                                                               | 3                   | HDdouble, HDfloat | mm    |
| HD_LAST_VELOCITY         | Get the last velocity of the device. Note: this value is smoothed to reduce high frequency jitter.                                                                                                                   | 3                   | HDdouble, HDfloat | mm/s  |
| HD_LAST_TRANSFORM        | Get the last row-major transform of the device end-effector.                                                                                                                                                         | 16                  | HDdouble, HDfloat |       |
| HD_LAST_ANGULAR_VELOCITY | Get the last Cartesian angular velocity of the device gimbal.                                                                                                                                                        | 3                   | HDdouble, HDfloat | rad   |
| HD_LAST_JOINT_ANGLES     | Get the last joint angles of the device. These are joint angles used for computing the kinematics of the armature relative to the base frame of the device. For PHANTOM devices: Turet Left +, Thigh Up +, Shin Up + | 3                   | HDdouble, HDfloat | rad   |
| HD_LAST_GIMBAL_ANGLES    | Get the last angles of the device gimbal. For PHANTOM devices: From Neutral position Right is +, Up is -, CW is +                                                                                                    | 3                   | HDdouble, HDfloat | rad/s |

**Table A-5: Get Safety Parameters**

| Parameter Name                  | Description                                                                                                                                                                               | Number of Arguments | Allowed Types     | Units                    |
|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|-------------------|--------------------------|
| HD_NOMINAL_MAX_STIFFNESS        | Get the maximum closed loop stiffness that is recommended for the device, i.e. the spring constant used in $F=kx$ output where $k$ is the spring constant and $x$ is the spring length.   | 1                   | HDfloat, HDdouble | 0 to 1                   |
| HD_NOMINAL_MAX_DAMPING          | Get the maximum level of damping that is recommended for the device, i.e. the damping constant used in $F=kx-dv$ where $d$ is the damping constant and $v$ is the velocity of the device. | 1                   | HDfloat, HDdouble | 0 to 1                   |
| HD_NOMINAL_MAX_FORCE            | Get the nominal maximum force, i.e. the amount of force that the device can sustain when the motors are at room temperature (optimal).                                                    | 1                   | HDfloat, HDdouble | N                        |
| HD_NOMINAL_MAX_CONTINUOUS_FORCE | Get the nominal maximum continuous force, i.e. the amount of force that the device can sustain through a period of time.                                                                  | 1                   | HDfloat, HDdouble | N                        |
| HD_MOTOR_TEMPERATURE            | Get the motor temperature, which is the predicted temperature of all of the motors.                                                                                                       | 3 or 6              | HDfloat, HDdouble | 0(coldest) to 1(warmest) |
| HD_SOFTWARE_VELOCITY_LIMIT      | Get the software maximum velocity limit. This does not replace the hardware limit of the device.                                                                                          | 1                   | HDfloat, HDdouble | mm/s                     |
| HD_SOFTWARE_FORCE_IMPULSE_LIMIT | Get the software maximum force impulse limit. This does not replace the hardware limit of the device                                                                                      | 1                   | HDfloat           | N                        |
| HD_FORCE_RAMPING_RATE           | Get the force ramping rate, which is the rate that the device ramps up forces when the scheduler is started or after an error.                                                            | 1                   | HDfloat, HDdouble | N/s                      |

**Table A-6: Get Scheduler Update Codes Parameters**

| Parameter Name               | Description                                                                                                     | Number of Arguments | Allowed Types | Units |
|------------------------------|-----------------------------------------------------------------------------------------------------------------|---------------------|---------------|-------|
| HD_UPDATE_RATE               | Get the average update rate of the device, i.e. the number of updates that the scheduler performs per second.   | 1                   | HDint         | Hz    |
| HD_INSTANTANEOUS_UPDATE_RATE | Get the instantaneous update rate of the device, i.e. 1/T where T is the time in seconds since the last update. | 1                   | HDint         | Hz    |

---

## Set Parameters

**Table A-7: Set Parameters**

| Parameter Name       | Description                                  | Number of Arguments | Allowed Types | Units |
|----------------------|----------------------------------------------|---------------------|---------------|-------|
| HD_USER_STATUS_LIGHT | Allows the user to set the LED status light. | 1                   | HDint         |       |

**Table A-8: Set Forces Parameters**

| Parameter Name    | Description                                                                                                                                                                                                            | Number of Arguments | Allowed Types        | Units |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|-------|
| HD_CURRENT_FORCE  | Set the current force as Cartesian coordinated vector. This is the primary method for sending forces to the device. Setting the current force causes that force to be commanded at end of the frame.                   | 3                   | HDfloat,<br>HDdouble | N     |
| HD_CURRENT_TORQUE | Set the current torque Cartesian coordinated vector, for 6DOF devices This is the primary method for sending torques to the device. Setting the current torque causes that torque to be commanded at end of the frame. | 3                   | HDfloat,<br>HDdouble | Nm    |

**Table A-8: Set Forces Parameters**

|                             |                                                                                                                                                                                                             |        |                   |                                      |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-------------------|--------------------------------------|
| HD_CURRENT_MOTOR_DAC_VALUES | Set the current motor DAC values. This is the primary method for commanding the amount of motor torque counts. This method cannot presently be used in combination with Cartesian force or torque commands. | 3 or 6 | HDlong            | Inclusive range of "[-32767, 32766]" |
| HD_CURRENT_JOINT_TORQUE     | Set the current torque as a joint coordinated vector for the first three joints of the PHANTOM device. Setting the current joint torque causes that torque to be commanded at end of the frame.             | 3      | HDfloat, HDdouble | mNm                                  |
| HD_CURRENT_GIMBAL_TORQUE    | Set current gimbal torque as a joint coordinated vector for the three gimbal joints of the PHANTOM 6DOF device. Setting the current gimbal torque causes that torque to be commanded at end of the frame.   | 3      | HDfloat, HDdouble | mNm                                  |

**Table A-9: Set Safety Parameters**

| Parameter Name                  | Description                                                                                                                                                                             | Number of Arguments | Allowed Types        | Units |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|----------------------|-------|
| HD_SOFTWARE_VELOCITY_LIMIT      | Set the software maximum velocity limit. This does not replace the hardware limit of the device.                                                                                        | 1                   | HDfloat,<br>HDdouble | mm/s  |
| HD_SOFTWARE_FORCE_IMPULSE_LIMIT | Sets the software maximum force impulse limit, which is the maximum change in magnitude and direction calculated by taking the difference between the current and last commanded force. | 1                   | HDfloat,<br>HDdouble | N/ms  |
| HD_FORCE_RAMPING_RATE           | Set the force ramping rate, which is the rate that the device ramps up forces when the scheduler is started or after an error.                                                          | 1                   | HDfloat,<br>HDdouble | N/s   |

## Capability Parameters

**Table A-10: hdEnable, hdDisable Parameters**

| Parameter Name                  | Description                                                                                                                                                                                                                                      |
|---------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HD_FORCE_OUTPUT                 | Enables or disables force output for the device. All motors are turned on or off.                                                                                                                                                                |
| HD_MAX_FORCE_CLAMPING           | Enables or disables max force clamping for the device. If enabled, this will clamp the overall force output magnitude to the maximum achievable.                                                                                                 |
| HD_FORCE_RAMPING                | Enables or disables force ramping, i.e. whether the device ramps up forces when the scheduler is turned on.                                                                                                                                      |
| HD_SOFTWARE_FORCE_LIMIT         | Enables or disables the software maximum force check, which returns an error if the force magnitude commanded to the device exceeds the maximum force limit. This is primarily to disable force kicking. Disable this at your own risk.          |
| HD_SOFTWARE_VELOCITY_LIMIT      | Enables or disables the software maximum velocity check, which returns an error if the velocity magnitude commanded to the device exceeds the maximum velocity limit. This is primarily to disable force kicking. Disable this at your own risk. |
| HD_SOFTWARE_FORCE_IMPULSE_LIMIT | Enables or disables the software maximum force impulse check, which prevents changes in force impulse and direction that exceed the change of impulse limit. This is primarily to prevent device kicking. Disable this at your own risk.         |
| HD_ONE_FRAME_LIMIT              | Enables or disables the one frame limit check, which restricts the application to one haptics frame per scheduler tick. This should only be disabled if the developer is running his own scheduler.                                              |
| HD_USER_STATUS_LIGHT            | Enables or disables user specified setting of the LED status light on the device.                                                                                                                                                                |

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## Codes

**Table A-11: Calibration Return Codes**

| Parameter Name                    | Description                                                                                                                                                                                                    |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HD_CALIBRATION_OK                 | Calibration is accurate.                                                                                                                                                                                       |
| HD_CALIBRATION_NEEDS_UPDATE       | Calibration needs an update. Call <b>hdUpdateCalibration()</b> to have the device update its calibration.                                                                                                      |
| HD_CALIBRATION_NEEDS_MANUAL_INPUT | Calibration needs manual input, such as having the user put the device in a reset position or inkwell. Once the user does this, further calls should no longer return that the calibration needs manual input. |

**Table A-12: Calibration Styles**

| Parameter Name               | Description                                                                                                     |
|------------------------------|-----------------------------------------------------------------------------------------------------------------|
| HD_CALIBRATION_ENCODER_RESET | The device needs to be put in a reset position to be calibrated.                                                |
| HD_CALIBRATION_AUTO          | The device will gather new calibration information as the armature is moved.                                    |
| HD_CALIBRATION_INKWELL       | Inkwell calibration. The device needs to put into a fixture, i.e. inkwell, before calibration can be performed. |



**Table A-13: Device Button Codes**

| Parameter Name                     | Description                                                                                         |
|------------------------------------|-----------------------------------------------------------------------------------------------------|
| HD_DEVICE_BUTTON_N (N=1,2,3, or 4) | Button states for current and last buttons. Use bitwise & to extract individual button information. |

**Table A-14: Scheduler Priority Codes**

| Parameter Name                | Description                                                                                                                                                                     |
|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HD_MAX_SCHEDULER_PRIORITY     | Maximum priority for a scheduler callback. Setting a callback with this priority means that the callback will be run first every scheduler tick in relation to other callbacks. |
| HD_MIN_SCHEDULER_PRIORITY     | Minimum priority for a scheduler callback. Setting a callback with this priority means that the callback will be run last every scheduler tick in relation to other callbacks.  |
| HD_DEFAULT_SCHEDULER_PRIORITY | Default scheduler priority. Set this for callbacks that do not care about when they are executed during the scheduler tick. This value is between min and max priority.         |

**Table A-15: Device Error Codes**

| Error Code                    | Description                                                                                                           |
|-------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| HD_SUCCESS                    | No error                                                                                                              |
| HD_INVALID_ENUM               | Invalid parameter of capability specified for a function that requires an HDenum as one of its inputs.                |
| HD_INVALID_VALUE              | Invalid value specified for a function that is attempting to set a value.                                             |
| HD_INVALID_OPERATION          | The operation could not be performed.                                                                                 |
| HD_INVALID_INPUT_TYPE         | The parameter or capability does not support the input type.                                                          |
| HD_BAD_HANDLE                 | The device handle passed into an operation is not valid.                                                              |
| HD_WARM_MOTORS                | Device Warning: One or more of the device motors are warm. Wait until the motors cool before commanding forces again. |
| HD_EXCEEDED_MAX_FORCE         | Device warning: Device exceeded the maximum force limit.                                                              |
| HD_EXCEEDED_MAX_FORCE_IMPULSE | Device warning: Change in force magnitude and direction exceeds the maximum force impulse limit.                      |
| HD_EXCEEDED_MAX_VELOCITY      | Device warning: Device exceeded the maximum velocity limit.                                                           |

**Table A-15: Device Error Codes**

|                             |                                                                                                                                                 |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| HD_FORCE_ERROR              | The device experienced an error in sending forces because forces of incompatible types such as DAC and Cartesian were commanded simultaneously. |
| HD_DEVICE_FAULT             | Device fault. Check that the device is connected properly and activated.                                                                        |
| HD_DEVICE_ALREADY_INITIATED | The device name was already initialized.                                                                                                        |
| HD_COMM_ERROR               | Communication Error: Check the device connection and configuration.                                                                             |
| HD_COMM_CONFIG_ERROR        | Configuration Error: Check the base address and port/adaptor number. Consult the appropriate device drivers documentation.                      |
| HD_TIMER_ERROR              | Unable to start or maintain the servo loop timer.                                                                                               |
| HD_ILLEGAL_BEGIN            | <b>hdBeginFrame()</b> for a device was called when already in that device's frame, or more than once during a single servo loop tick.           |
| HD_ILLEGAL_END              | <b>hdEndFrame()</b> for a device was called without a matching <b>hdBeginFrame()</b> for that device beforehand.                                |
| HD_FRAME_ERROR              | A function that is restricted to being called within a frame was called outside of one.                                                         |
| HD_INVALID_PRIORITY         | The priority for a scheduler callback does not fall within the proper numerical bounds defined by MIN and MAX scheduler priority.               |
| HD_SCHEDULER_FULL           | The scheduler has reached its limit of callbacks and cannot add the new callback.                                                               |
| HD_INVALID_LICENSE          | The required license is invalid or missing.                                                                                                     |

# Haptic Library API Parameters

The following pages contain tables that list the names of the HLAPI parameters. For each parameter the table lists a description.

The parameters are grouped as follows:

| <b>Topic</b>                    | <b>Page</b> |
|---------------------------------|-------------|
| State Maintenance Parameters    | B-2         |
| Shape Parameters                | B-8         |
| Shape Parameters                | B-8         |
| Material and Surface Parameters | B-10        |
| Force Effect Parameters         | B-13        |
| Callback Parameters             | B-16        |
| Event Parameters                | B-17        |
| Proxy Parameters                | B-18        |
| Transform Parameters            | B-19        |

## State Maintenance Parameters

**Table B-1: hlGetBooleanv, hlGetIntegerv, hlGetDoublev**

| Parameter Name                    | Description                                                                                                                                                                                       |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_BUTTON1_STATE                  | Single Boolean value representing the first button on the haptic device. A value of true means that the button is depressed.                                                                      |
| HL_BUTTON2_STATE                  | Single Boolean value representing the second button on the haptic device. A value of true means that the button is depressed.                                                                     |
| HL_SAFETY_STATE                   | Single Boolean value representing the safety switch on the haptic device, if on exists. A value of true means that the switch is depressed.                                                       |
| HL_INKWELL_STATE                  | Single Boolean value representing the inkwell switch on the haptic device, if on exists. A value of true means that the switch is depressed.                                                      |
| HL_DEPTH_OF_PENETRATION           | Double precision value representing the depth of the penetration of the device in world coordinates. This will return the depth of penetration for the current object being touched by the proxy. |
| HL_DEVICE_FORCE                   | Vector of 3 doubles representing the last force, in world coordinates, sent to the haptic device.                                                                                                 |
| HL_DEVICE_POSITION                | Vector of 3 doubles representing the position of the haptic device in world coordinates.                                                                                                          |
| HL_DEVICE_ROTATION                | Vector of 4 doubles representing a quaternion that specifies the rotation of the haptic device in world coordinates.                                                                              |
| HL_DEVICE_TORQUE                  | Vector of 3 doubles representing the last torque, in world coordinates, sent to the haptic device.                                                                                                |
| HL_DEVICE_TRANSFORM               | Vector of 16 doubles representing a 4x4 transform matrix in column major order that specifies the transform of the haptic device relative to world coordinates.                                   |
| HL_EVENT_MOTION_ANGULAR_TOLERANCE | Double precision value representing the minimum rotation, in radians, that the proxy must move before a motion event is triggered.                                                                |
| HL_EVENT_MOTION_LINEAR_TOLERANCE  | Double precision value representing the minimum distance, in device workspace coordinates, that the proxy must move before a motion event is triggered.                                           |

**Table B-1: hlGetBooleany, hlGetIntegerv, hlGetDoublev**

|                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_GOLDEN_POSITION   | A vector of 3 doubles representing the golden sphere center position in world coordinates. The golden sphere is a bounding volume for the proxy and designates the space of allowed proxy movement for a particular HL frame. The client is responsible for providing geometry within this bounding volume. Typically, this bounding volume gets used for sizing the graphic view volume when the haptic camera view is enabled. The adaptive viewport optimization also references this golden sphere for determining how much of the depth buffer to read back. Additionally, the golden sphere can be useful when implementing a callback shape or performing bounding volume culling. The radius of the sphere may be queried using HL_GOLDEN_RADIUS.  |
| HL_GOLDEN_RADIUS     | Double precision value representing the radius of the golden sphere in world coordinates. The golden sphere is a bounding volume for the proxy and designates the space of allowed proxy movement for a particular HL frame. The client is responsible for providing geometry within this bounding volume. Typically, this bounding volume gets used for sizing the graphic view volume when the haptic camera view is enabled. The adaptive viewport optimization also references this golden sphere for determining how much of the depth buffer to read back. Additionally, the golden sphere can be useful when implementing a callback shape or performing bounding volume culling. The center of the sphere may be queried using HL_GOLDEN_POSITION. |
| HL_MODELVIEW         | Array of sixteen doubles representing a 4x4 transform matrix in column major order that specifies the transform from model coordinates to view coordinates. This matrix is only applied when not using the OpenGL modelview (when HL_USE_GL_MODELVIEW is disabled). When the OpenGL modelview is used, you should use OpenGL functions to query the modelview matrix.                                                                                                                                                                                                                                                                                                                                                                                      |
| HL_PROXY_IS_TOUCHING | Single Boolean value set to true when the proxy is in contact with one or more shapes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| HL_PROXY_POSITION    | Vector of 3 doubles representing the position of the proxy in world coordinates.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| HL_PROXY_ROTATION    | Vector of 4 doubles representing a quaternion that specifies the rotation of the proxy in world coordinates.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| HL_TOUCHABLE_FACE    | Get the touchable face for the model, which represents which side of the model can be felt. See Table B-10 for a list of return values.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

**Table B-1: hlGetBooleanv, hlGetIntegerv, hlGetDoublev**

|                          |                                                                                                                                                                             |
|--------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                          | Gets the integer touch type, which represents how the proxy interacts with the model. See Table B-15 for a list of return values.                                           |
| HL_PROXY_TOUCH_NORMAL    | A vector of 3 doubles representing the surface normal at the point of contact with the set of shapes in contact with the proxy. Only valid if HL_PROXY_IS_TOUCHING is true. |
| HL_PROXY_TRANSFORM       | Vector of 16 doubles representing a 4x4 transform matrix in column major order that specifies the transform of the proxy relative to world coordinates                      |
| HL_TOUCHWORKSPACE_MATRIX | Array of sixteen doubles representing a 4x4 transform matrix in column major order that specifies the transform from touch coordinates to workspace coordinates.            |
| HL_VIEWTOUCH             | Array of sixteen doubles representing a 4x4 transform matrix in column major order that specifies the transform from view coordinates to touch coordinates.                 |

**Table B-2: hlCacheGetBooleanv, hlCacheGetDoublev**

| Parameter Name        | Description                                                                                                                                                                 |
|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_BUTTON1_STATE      | Single Boolean value representing the first button on the haptic device. A value of true means that the button is depressed.                                                |
| HL_BUTTON2_STATE      | Single Boolean value representing the second button on the haptic device. A value of true means that the button is depressed.                                               |
| HL_SAFETY_STATE       | Single Boolean value representing the safety switch on the haptic device, if on exists. A value of true means that the switch is depressed.                                 |
| HL_INKWELL_STATE      | Single Boolean value representing the inkwell switch on the haptic device, if on exists. A value of true means that the switch is depressed.                                |
| HL_DEVICE_FORCE       | Vector of 3 doubles representing the last force, in world coordinates, sent to the haptic device.                                                                           |
| HL_DEVICE_POSITION    | Vector of 3 doubles representing the position of the haptic device in world coordinates.                                                                                    |
| HL_DEVICE_ROTATION    | Vector of 4 doubles representing a quaternion that specifies the rotation of the haptic device in world coordinates.                                                        |
| HL_DEVICE_TORQUE      | Vector of 3 doubles representing the last torque, in world coordinates, sent to the haptic device.                                                                          |
| HL_DEVICE_TRANSFORM   | Vector of 16 doubles representing a 4x4 transform matrix in column major order that specifies the transform of the haptic device relative to world coordinates.             |
| HL_PROXY_IS_TOUCHING  | Single Boolean value set to true when the proxy is in contact with one or more shapes.                                                                                      |
| HL_PROXY_POSITION     | Vector of 3 doubles representing the position of the proxy in world coordinates.                                                                                            |
| HL_PROXY_ROTATION     | Vector of 4 doubles representing a quaternion that specifies the rotation of the proxy in world coordinates.                                                                |
| HL_PROXY_TOUCH_NORMAL | A vector of 3 doubles representing the surface normal at the point of contact with the set of shapes in contact with the proxy. Only valid if HL_PROXY_IS_TOUCHING is true. |
| HL_PROXY_TRANSFORM    | Vector of 16 doubles representing a 4x4 transform matrix in column major order that specifies the transform of the proxy relative to world coordinates.                     |

**Table B-3: hlGetError**

| Parameter Name       | Description                                                                                                                                                                                                                                                                                                                                                                     |
|----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_DEVICE_ERROR      | An error occurred with the haptic device. The errorInfo field of the HLError struct will contain a device specific error code. See hdefine.h for a list of device errors. This error may be signaled even outside any API function calls if the device error is detected in the haptic rendering engine running in a separate thread. The haptic device recovers in most cases. |
| HL_INVALID_ENUM      | An invalid value for an enumerated type was passed to an API function. The function call will have no effect other than to set the error.                                                                                                                                                                                                                                       |
| HL_INVALID_OPERATION | An API function was called when the renderer was not in an appropriate state for that function call. For example, <b>hlBeginShape()</b> was called outside an <b>hlBeginFrame()/hlEndFrame()</b> pair, or <b>hlBeginFrame()</b> when no haptic rendering context was active. The function call will have no effect other than to set the error.                                 |
| HL_INVALID_VALUE     | A value passed to an API function is outside the valid range for that function. The function call will have no effect other than to set the error.                                                                                                                                                                                                                              |
| HL_NO_ERROR          | No error. There were no errors from API function calls since the last time the error stack was empty; the error stack can be empty if either no errors have ever occurred or all errors have been already queried from the stack.                                                                                                                                               |
| HL_OUT_OF_MEMORY     | There is not enough memory to complete the last API function called. This function may have partially completed leaving the haptic renderer in an undefined state.                                                                                                                                                                                                              |
| HL_STACK_OVERFLOW    | An API function was called that would have caused an overflow of the matrix stack. The function call will have no effect other than to set the error.                                                                                                                                                                                                                           |
| HL_STACK_UNDERFLOW   | An API function was called that would have caused an underflow of the matrix stack, i.e. a call to <b>hlPopMatrix()</b> when the stack is empty. The function call will have no effect other than to set the error.                                                                                                                                                             |



**Table B-4: hlGetString**

| Parameter Name | Description                                                                                                                |
|----------------|----------------------------------------------------------------------------------------------------------------------------|
| HL_VENDOR      | Returns the name of the company responsible for the haptic renderer implementation.                                        |
| HL_VERSION     | Returns the version number of the haptic rendering library as a string of the form: major_number.minor_number.build_number |

**Table B-5: hlHinti, hlHintb**

| Parameter Name                    | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|-----------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_SHAPE_DYNAMIC_SURFACE_CHANGE   | A single Boolean value indicating whether or not shapes that follow should be treated as dynamically changing surfaces. A value of true tells the haptic rendering engine to do extra processing to ensure that the proxy does not fall through a dynamically changing surface. A value of false tells the rendering engine to optimize haptic rendering for surfaces which will not change.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| HL_SHAPE_FEEDBACK_BUFFER_VERTICES | A single integer value indicating to the haptic rendering engine approximately how many vertices will be in the next feedback buffer shape so that it may reserve the correct amount of memory.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| HL_SHAPE_PERSISTENCE              | <p>A single boolean value indicating whether or not shapes that follow should persistent beyond the current frame. A value of true tells the haptic renderer that the shape does not need to be respecified during the next frame, but that it should be automatically included. This is useful particularly for background objects, i.e. static objects that change rarely in the scene, since those objects can just be specified once and left in the scene versus having the scene recompute the object for each frame. To clear a persistent shape, set it as non-persistent during any frame afterward.</p> <p>LIMITATION: This feature will not work if HL_HAPTIC_CAMERA_VIEW is enabled.</p> <p>NOTE: This is a minimally supported experimental feature for v2.0. It will most likely be deprecated, removed, or replaced by alternate API command in the next release.</p> |

## Shape Parameters

**Table B-6: hlBegin Shape**

| Parameter Name           | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_SHAPE_CALLBACK        | Allows clients to create custom shapes not supported using the other shape types. OpenGL commands are ignored for this shape type. No geometry is specified. Instead, the current shape intersection and shape closest point callbacks are used for haptic rendering of this shape.                                                                                                                                                                                                                                                                                                                                                                      |
| HL_SHAPE_DEPTH_BUFFER    | OpenGL commands used following the <b>hlBeginShape()</b> call will generate an image in the OpenGL depth buffer. When <b>hlEndShape()</b> is called, this image will be read out of the depth buffer and sent to the haptic renderer. Any OpenGL commands that modify the depth buffer may be used. Point and line constraints may not be specified using a depth buffer shape.                                                                                                                                                                                                                                                                          |
| HL_SHAPE_FEEDBACK_BUFFER | OpenGL commands used following the <b>hlBeginShape()</b> call will generate a set of geometric primitives (quads, triangles, points and lines) that will be sent to the OpenGL feedback buffer. When <b>hlEndShape()</b> is called, these primitives will be read out of the feedback buffer and sent to the haptic renderer. Feedback buffer shapes can be used to specify triangles meshes as well as points and lines for constraints. For optimal memory usage and performance, use <b>hlHint()</b> with <b>HL_SHAPE_FEEDBACK_BUFFER_VERTICES</b> before <b>hlBeginShape()</b> , so that the size of the feedback buffer may be optimally allocated. |

**Table B-7: hlGetShapeBooleany, hlGetShapeDoublev**

| Parameter Name       | Description                                                                                                                                                                                                                                   |
|----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_PROXY_IS_TOUCHING | Single Boolean value. True means that the proxy is currently in contact with the shape.                                                                                                                                                       |
| HL_REACTION_FORCE    | Vector of 3 doubles representing the contribution of this shape to the overall reaction force that was sent to the haptic device during the last frame. If the proxy was not in contact with this shape last frame, this vector will be zero. |

**Table B-8: hlLocalFeature types**

| Type Name              | Description                                                                                                          |
|------------------------|----------------------------------------------------------------------------------------------------------------------|
| HL_LOCAL_FEATURE_LINE  | The local feature is a line segment whose start point and end point are given by the vectors v1 and v2 respectively. |
| HL_LOCAL_FEATURE_PLANE | The local feature is a plane whose normal is given by the vector v1 and that passes through the point v1.            |
| HL_LOCAL_FEATURE_POINT | The local feature is a single point whose position is given by the vector v.                                         |

---

## Capability Parameters

**Table B-9: hlEnable, hlDisable, hlIsEnabled**

| Parameter Name        | Description                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_ADAPTIVE_VIEWPORT  | If enabled, this feature serves as an optimization for single pass rendering of depth buffer shapes. This feature adaptively sizes the read-back pixel dimensions of the viewport based on the location and motion of the proxy. This feature is incompatible with haptic camera view. This is disabled by default.                                                                                                              |
| HL_HAPTIC_CAMERA_VIEW | Enhances shape rendering by modifying the shape viewing transform based on the motion of the proxy. This allows the user to feel depth buffer features that are occluded in the primary camera view. The haptic camera view also serves as an optimization by sizing the viewing volume and viewport so that the graphics pipeline only processes geometry that is within a proximity to the proxy. This is disabled by default. |
| HL_PROXY_RESOLUTION   | If enabled, use shape geometry to automatically update the proxy position. The computed proxy position will be valid for all shapes specified each frame. If disabled, shapes will be ignored and the proxy position will be set by the client program. This is enabled by default.                                                                                                                                              |
| HL_USE_GL_MODELVIEW   | If enabled, apply the OpenGL modelview matrix to all geometry for haptic rendering and ignore the current HL_MODELVIEW setting. This should be disabled in HLAPI programs that do not have a valid OpenGL rendering context query. It is enabled by default.                                                                                                                                                                     |

## Material and Surface Parameters

**Table B-10: hlMaterialf - face values**

| Parameter Name    | Description                                                                                                                                                                                                                           |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_FRONT          | Apply the material property only to the front face of shapes and to all faces of constraints.                                                                                                                                         |
| HL_BACK           | Apply the material property only to the back face of shapes and to all faces of constraints.                                                                                                                                          |
| HL_FRONT_AND_BACK | Apply the material property to both front and back faces.                                                                                                                                                                             |
| HL_POPTHROUGH     | Popthrough controls the amount of force the user must apply to a shape before the device pops through the shape to the other side. The larger the param value, the higher the force required. A param value of 0 disables popthrough. |

**Table B-11: hlMaterialf - pname values**

| Parameter Name      | Description                                                                                                                                                                                                                                                                                                                                                  |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_STIFFNESS        | Stiffness controls how hard surfaces feel. Param must be a value between 0 and 1 where 1 represents the hardest surface the haptic device is capable of rendering and 0 represents the most compliant surface that can be rendered.                                                                                                                          |
| HL_DAMPING          | Damping reduces the springiness of the surface. Param must be between 0 and 1 where 0 represents no damping, i.e. a highly springy surface and 1 represents the maximum level of damping possible                                                                                                                                                            |
| HL_STATIC_FRICTION  | Static friction controls the resistance of a surface to tangential motion when the proxy position is not changing i.e. how hard it is to slide along the surface starting from a complete stop. A param value of 0 is a completely frictionless surface and a value of 1 is the maximum amount of static friction the haptic device is capable of rendering. |
| HL_DYNAMIC_FRICTION | Dynamic friction controls the resistance of a surface to tangential motion when the proxy position is changing i.e. how hard it is to slide along the surface once already moving. A param value of 0 is a completely frictionless surface and a value of 1 is the maximum amount of dynamic friction the haptic device is capable of rendering.             |

**Table B-12: hlGetMaterialfv - face values**

| Parameter Name | Description                                                                  |
|----------------|------------------------------------------------------------------------------|
| HL_FRONT       | Query the material property of the front face of shapes and all constraints. |
| HL_BACK        | Query the material property of the back face of shapes and all constraints.  |

**Table B-13: hlGetMaterialfv - pname values**

| Parameter Name      | Description                                                                                                                                                                                                                                                                                                                                                  |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_STIFFNESS        | Stiffness controls how hard surfaces feel. Param must be a value between 0 and 1 where 1 represents the hardest surface the haptic device is capable of rendering and 0 represents the most compliant surface that can be rendered.                                                                                                                          |
| HL_DAMPING          | Damping reduces the springiness of the surface. Param must be between 0 and 1 where 0 represents no damping, i.e. a highly springy surface and 1 represents the maximum level of damping possible.                                                                                                                                                           |
| HL_STATIC_FRICTION  | Static friction controls the resistance of a surface to tangential motion when the proxy position is not changing i.e. how hard it is to slide along the surface starting from a complete stop. A param value of 0 is a completely frictionless surface and a value of 1 is the maximum amount of static friction the haptic device is capable of rendering. |
| HL_DYNAMIC_FRICTION | Dynamic friction controls the resistance of a surface to tangential motion when the proxy position is changing i.e. how hard it is to slide along the surface once already moving. A param value of 0 is a completely frictionless surface and a value of 1 is the maximum amount of dynamic friction the haptic device is capable of rendering.             |
| HL_POPTHROUGH       | Popthrough controls the amount of force the user must apply to a shape before the device pops through the shape to the other side. The larger the param value, the higher the force required. Param must be between 0 and 1 where a value of 0 disables popthrough.                                                                                          |

**Table B-14: hlTouchableFace - mode values**

| Parameter Name    | Description                                        |
|-------------------|----------------------------------------------------|
| HL_FRONT          | Only front faces will be touchable.                |
| HL_BACK           | Only back faces will be touchable.                 |
| HL_FRONT_AND_BACK | All faces, both front and back, will be touchable. |

**Table B-15: hITouchModel**

| Parameter Name | Description                                                                                                                                                                                                                         |
|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_CONTACT     | The proxy position is not allowed to pass through geometric primitives (triangles). The proxy may move off the surface but it will remain on one side of it.                                                                        |
| HL_CONSTRAINT  | The proxy position is constrained to remain exactly on the surface of geometric primitives and it may only be moved off of the surface if the distance between the device position and the proxy is greater than the snap distance. |

**Table B-16: hITouchModelIf**

| Parameter Name   | Description                                                                                                                                                                                                                                                     |
|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_SNAP_DISTANCE | Distance between the proxy position and the surface that must be exceeded to pull off a constraint. Param should be a floating point value representing the distance in millimeters in workspace coordinates. The default value is FLT_MAX to always be active. |

## Force Effect Parameters

**Table B-17: hlStartEffect - effect types**

| Parameter Name     | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_EFFECT_CONSTANT | Adds a constant force vector to the total force sent to the haptic device. The effect property HL_EFFECT_PROPERTY_DIRECTION specifies the direction of the force vector. The effect property HL_EFFECT_PROPERTY_MAGNITUDE specifies the magnitude of the force vector.                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| HL_EFFECT_SPRING   | Adds a spring force to the total force sent to the haptic device. The spring force pulls the haptic device towards the effect position and is proportional to the product of the gain and the distance between the effect position and the device position. Specifically, the spring force is calculated using the expression $F = k(P-X)$ where F is the spring force, P is the effect position, X is the current haptic device position and k is the gain. The effect position is specified by the property HL_EFFECT_PROPERTY_POSITION. The gain is specified by the property HL_EFFECT_PROPERTY_GAIN. The magnitude of the effect force is capped at the value of the effect property HL_EFFECT_MAGNITUDE. |
| HL_EFFECT_VISCOUS  | Adds a viscous force to the total force sent to the haptic device. The viscous force is based on the current velocity of the haptic device and is calculated to resist the motion of the haptic device. Specifically the force is calculated using the expression $F = -kV$ where f is the spring force, V is the velocity and k is the gain. The gain is specified by the property HL_EFFECT_PROPERTY_GAIN. The magnitude of the effect force is capped at the value of the effect property HL_EFFECT_MAGNITUDE.                                                                                                                                                                                              |
| HL_EFFECT_FRICTION | Adds a friction force to the total force sent to the haptic device. Unlike friction specified via <b>hlMaterial()</b> calls, this is friction both while touching objects and in free space. The gain of the friction force is specified by the property HL_EFFECT_PROPERTY_GAIN. The magnitude of the effect force is capped at the value of the effect property HL_EFFECT_MAGNITUDE.                                                                                                                                                                                                                                                                                                                         |
| HL_EFFECT_CALLBACK | Allows for the user to create a custom effect by setting effect callbacks using <b>hlCallback()</b> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |

Table B-18: `hlTriggerEffect`

| Parameter Name                  | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>HL_EFFECT_CONSTANT</code> | Adds a constant force vector to the total force sent to the haptic device. The effect property <code>HL_EFFECT_PROPERTY_DIRECTION</code> specifies the direction of the force vector. The effect property <code>HL_EFFECT_PROPERTY_MAGNITUDE</code> specifies the magnitude of the force vector.                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
| <code>HL_EFFECT_SPRING</code>   | Adds a spring force to the total force sent to the haptic device. The spring force pulls the haptic device towards the effect position and is proportional to the product of the gain and the distance between the effect position and the device position. Specifically, the spring force is calculated using the expression $F = k(P-X)$ where $F$ is the spring force, $P$ is the effect position, $X$ is the current haptic device position and $k$ is the gain. The effect position is specified by the property <code>HL_EFFECT_PROPERTY_POSITION</code> . The gain is specified by the property <code>HL_EFFECT_PROPERTY_GAIN</code> . The magnitude of the effect force is capped at the value of the effect property <code>HL_EFFECT_MAGNITUDE</code> . |
| <code>HL_EFFECT_VISCOUS</code>  | Adds a viscous force to the total force sent to the haptic device. The viscous force is based on the current velocity of the haptic device and is calculated to resist the motion of the haptic device. Specifically the force is calculated using the expression $F = -kV$ where $f$ is the spring force, $V$ is the velocity and $k$ is the gain. The gain is specified by the property <code>HL_EFFECT_PROPERTY_GAIN</code> . The magnitude of the effect force is capped at the value of the effect property <code>HL_EFFECT_MAGNITUDE</code> .                                                                                                                                                                                                              |
| <code>HL_EFFECT_FRICTION</code> | Adds a friction force to the total force sent to the haptic device. Unlike friction specified via <code>hlMaterial()</code> calls, this is friction both while touching objects and in free space. The gain of the friction force is specified by the property <code>HL_EFFECT_PROPERTY_GAIN</code> . The magnitude of the effect force is capped at the value of the effect property <code>HL_EFFECT_MAGNITUDE</code> .                                                                                                                                                                                                                                                                                                                                         |
| <code>HL_EFFECT_CALLBACK</code> | Allows for the user to create a custom effect by setting effect callbacks using <code>hlCallback()</code> .                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |



**Table B-19: hIEffectd, hIEffecti, hIEffectdv, hIEffectiv**

| Parameter Name               | Description                                                                                                                                                                              |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_EFFECT_PROPERTY_GAIN      | Used by spring, friction and viscous effect types. Higher gains will cause these effects to generate larger forces.                                                                      |
| HL_EFFECT_PROPERTY_MAGNITUDE | Used by constant, spring, friction and viscous effect types. Represents a cap on the maximum force generated by these effects.                                                           |
| HL_EFFECT_PROPERTY_FREQUENCY | Reserved for use by future effect types and callback effects.                                                                                                                            |
| HL_EFFECT_PROPERTY_DURATION  | Used for all effects started with a call to <b>hlTriggerEffect()</b> . The effect will automatically be terminated when the duration has elapsed. Duration is specified in milliseconds. |
| HL_EFFECT_PROPERTY_POSITION  | Used by spring effect. Represents the anchor position of the spring.                                                                                                                     |
| HL_EFFECT_PROPERTY_DIRECTION | Used by constant effect. Represents direction of constant force vector.                                                                                                                  |

**Table B-20: hlGetEffectdv, hlGetEffectiv, hlGetEffectbv**

| Parameter Name               | Description                                                                                                                                                                              |
|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_EFFECT_PROPERTY_GAIN      | Used by spring, friction and viscous effect types. Higher gains will cause these effects to generate larger forces.                                                                      |
| HL_EFFECT_PROPERTY_MAGNITUDE | Used by constant, spring, friction and viscous effect types. Represents a cap on the maximum force generated by these effects.                                                           |
| HL_EFFECT_PROPERTY_FREQUENCY | Reserved for use by future effect types and callback effects.                                                                                                                            |
| HL_EFFECT_PROPERTY_DURATION  | Used for all effects started with a call to <b>hlTriggerEffect()</b> . The effect will automatically be terminated when the duration has elapsed. Duration is specified in milliseconds. |
| HL_EFFECT_PROPERTY_POSITION  | Used by spring effect. Represents the anchor position of the spring.                                                                                                                     |
| HL_EFFECT_PROPERTY_DIRECTION | Used by constant effect. Represents direction of constant force vector.                                                                                                                  |
| HL_EFFECT_PROPERTY_ACTIVE    | Used by all effects. Indicates whether the effect is currently running, i.e. has been started via <b>hlStartEffect()</b> .                                                               |
| HL_EFFECT_PROPERTY_TYPE      | Used by all effect. Represents the type of effect, such as HL_EFFECT_CALLBACK, HL_EFFECT_SPRING.                                                                                         |

## Callback Parameters

**Table B-21: hlCallback**

| Parameter Name            | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_SHAPE_INTERSECT_LS     | <p>Callback to intersect a line segment with a user defined custom shape. The callback function must have the following signature:</p> <pre>HLboolean HLCALLBACK fn(const HLdouble startPt[3],                         const HLdouble endPt[3], HLdouble intersectionPt[3],                         HLdouble intersectionNormal[3], void *userdata)</pre> <p>Where input parameters startPt and endPt are the endpoints of a line segment to intersect with the custom shape, intersectionPt is used to return the point of intersection of the line segment with the shape. In the case of multiple intersections, intersectionPt should be the closest intersection to startPt. IntersectionNormal is the surface normal of the custom shape at intersectionPt. Userdata is the same userdata pointer passed to <b>hlCallback()</b>. The callback function should return true if the line segment intersects the shape. All data is in the local coordinate system of the custom shape.</p> |
| HL_SHAPE_CLOSEST_FEATURES | <p>Callback to find the closest point on the surface to an input point as well as one or more local features that approximate the surface in the vicinity of that point. The callback function must have the following signature:</p> <pre>HLboolean HLCALLBACK fn(const HLdouble queryPt[3], const HLdouble targetPt[3],                         HLgeom *geom, HLdouble closestPt[3], void* userdata)</pre> <p>Where closest point should be set to the closest point on the surface of the custom shape closest to the input parameter queryPt. Normal is the surface normal of the custom shape at closestPt. Userdata is the same userdata pointer passed to <b>hlCallback()</b>. All data is in the local coordinate system of the custom shape.</p>                                                                                                                                                                                                                                     |

## Event Parameters

**Table B-22: hlAddEventCallback, hlRemoveEventCallBack - event values:**

| Parameter Name       | Description                                                                                                                                                                                                                                                                                                                                                          |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_EVENT_MOTION      | Callback will be called when either the proxy has moved more than the HL_EVENT_MOTION_LINEAR_TOLERANCE millimeters in workspace coordinates from the position when the last motion event was triggered or when the proxy has been rotated more than HL_EVENT_MOTION_ANGULAR_TOLERANCE radians from the rotation of the proxy last time a motion event was triggered. |
| HL_EVENT_1BUTTONDOWN | Callback will be called when the first button on the haptic device is depressed.                                                                                                                                                                                                                                                                                     |
| HL_EVENT_1BUTTONUP   | Callback will be called when the first button on the haptic device is released.                                                                                                                                                                                                                                                                                      |
| HL_EVENT_2BUTTONDOWN | Callback will be called when the second button on the haptic device is depressed.                                                                                                                                                                                                                                                                                    |
| HL_EVENT_2BUTTONUP   | Callback will be called when the second button on the haptic device is released.                                                                                                                                                                                                                                                                                     |
| HL_EVENT_SAFETYDOWN  | Callback will be called when the safety switch, if available, is depressed.                                                                                                                                                                                                                                                                                          |
| HL_EVENT_SAFETYUP    | Callback will be called when the safety switch, if available, is released.                                                                                                                                                                                                                                                                                           |
| HL_EVENT_INKWELLDOWN | Callback will be called when the inkwell switch, if available, is depressed.                                                                                                                                                                                                                                                                                         |
| HL_EVENT_INKWELL_UP  | Callback will be called when the inkwell switch, if available, is released.                                                                                                                                                                                                                                                                                          |
| HL_EVENT_TOUCH       | Callback will be called when a shape in the scene has been touched (the proxy is in contact with the shape).                                                                                                                                                                                                                                                         |
| HL_EVENT_UNTOUCH     | Callback will be called when the shape in the scene is no longer being touched (the proxy was in contact with shape but is no longer in contact).                                                                                                                                                                                                                    |

**Table B-23: hlAddEventCallback, hlRemoveEventCallback - thread values**

| Parameter Name      | Description                                                                                                                                                                                                                                                                   |
|---------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_CLIENT_THREAD    | Callback function will be called from client thread, when the client program calls <b>hlCheckEvents()</b> .                                                                                                                                                                   |
| HL_COLLISION_THREAD | Callback function will be called from the internal collision thread running in the haptic rendering engine. Most event callbacks should be handled in the client thread, however there are some cases where collision thread callbacks are needed due to timing requirements. |

**Table B-24: hlEventd - pname values**

| Parameter Name                    | Description                                                                                                                                                                                  |
|-----------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_EVENT_MOTION_LINEAR_TOLERANCE  | Sets the minimum distance in device workspace coordinates, that the linear translation of the proxy must change before a motion event is triggered. By default this value is one millimeter. |
| HL_EVENT_MOTION_ANGULAR_TOLERANCE | Sets the minimum angular distance in, that orientation of the proxy must change before a motion event is triggered. By default this value is 0.02 radians.                                   |

---

## Proxy Parameters

**Table B-25: hlProxydv**

| Parameter Name    | Description                                                                                                         |
|-------------------|---------------------------------------------------------------------------------------------------------------------|
| HL_PROXY_POSITION | Sets the position of the proxy in world coordinates. If proxy resolution is enabled, this call will have no effect. |

## Transform Parameters

**Table B-26: hlMatrix - mode values**

| Parameter Name    | Description                                                                                                                                                                                                                  |
|-------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| HL_VIEWTOUCH      | All matrix manipulation commands will target the transform from view coordinates to touch coordinates.                                                                                                                       |
| HL_TOUCHWORKSPACE | All matrix manipulation commands will target the transform from touch coordinates to the local coordinates of the haptic device.                                                                                             |
| HL_MODELVIEW      | All matrix manipulation commands will target the transform from model coordinates to view coordinates. The HL_MODELVIEW is only applied when HL_USE_GL_MODELVIEW is disabled, otherwise the OpenGL modelview matrix is used. |

**Table B-27: hlPushAttrib, hlPopAttrib**

| Parameter Name   | Description                                                                                                                               |
|------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| HL_HINT_BIT      | Affects all properties that are set by <b>hlHint()</b> command such as HL_SHAPE_FEEDBACK_BUFFER.                                          |
| HL_MATERIAL_BIT  | Affects all properties that are specified by <b>hlMaterial()</b> commands such as HL_STIFFNESS, HL_DYNAMIC_FRICTION.                      |
| HL_TOUCH_BIT     | Affects all properties that are specified by <b>hlTouch()</b> commands, such as HL_SNAP_DISTANCE, HL_TOUCH_MODEL.                         |
| HL_TRANSFORM_BIT | Affects all transform and camera attributes, such as HL_HAPTIC_CAMERA_VIEW, HL_ADAPTIVE_VIEWPORT.                                         |
| HL_EFFECT_BIT    | Affects all properties that are specified by <b>hlEffect()</b> commands, such as HL_EFFECT_PROPERTY_GAIN, HL_EFFECT_PROPERTY_DURATION.    |
| HL_EVENTS_BIT    | Affects all properties that are specified by event commands, such as HL_EVENT_MOTION_LINEAR_THRESHOLD, HL_EVENT_MOTION_ANGULAR_TOLERANCE. |

**Table B-28: Calibration Event Types**

| Parameter Name              | Description                                                                                  |
|-----------------------------|----------------------------------------------------------------------------------------------|
| HL_EVENT_CALIBRATION_UPDATE | Triggers when valid calibration data has been found.                                         |
| HL_EVENT_CALIBRATION_INPUT  | Triggers when the device requires user input, such as inserting the stylus into the inkwell. |



B HAPTIC LIBRARY API PARAMETERS  
*Transform Parameters*



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