

# GLFW

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## Reference Manual

**API version 2.7**

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# Summary

This document is primarily a function reference manual for the GLFW API. For a description of how to use GLFW you should refer to the *GLFW Users Guide*.

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# Chapter 1

## Introduction

GLFW is a portable API (Application Program Interface) that handles operating system specific tasks related to OpenGL<sup>®</sup> programming. While OpenGL<sup>®</sup> in general is portable, easy to use and often results in tidy and compact code, the operating system specific mechanisms that are required to set up and manage an OpenGL<sup>®</sup> window are quite the opposite. GLFW tries to remedy this by providing the following functionality:

- Opening and managing an OpenGL<sup>®</sup> context and its associated window.
- Keyboard, mouse and joystick input.
- A high precision timer.
- Multi-threading support.
- Support for querying and using OpenGL<sup>®</sup> extensions.
- Basic Targa image loading support.

All this functionality is implemented as a set of easy-to-use functions, which makes it possible to write an OpenGL<sup>®</sup> application framework in just a few lines of code. The GLFW API looks and behaves the same on all supported platforms, making it very simple to port GLFW based OpenGL<sup>®</sup> applications to a variety of platforms.

Currently supported platforms are:

- Microsoft Windows<sup>®</sup> (32-bit only).
- Unix<sup>®</sup> or Unix-like systems running reasonably a modern version of the X Window System<sup>TM1</sup>  
e.g. Linux<sup>®</sup>, FreeBSD<sup>®</sup> and Solaris<sup>TM</sup> (32- and 64-bit).

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<sup>1</sup>X11.app on Mac OS X is not supported due to its incomplete implementation of GLXFBConfigs

## Chapter 2

# GLFW Operation Overview

### 2.1 The GLFW Window

GLFW only supports having one window open at a time. The window can be either a normal desktop window or a fullscreen window. The latter is completely undecorated, without window borders, and covers the entire monitor. With a fullscreen window, it is also possible to select which video mode to use.

When a window is opened, an OpenGL<sup>®</sup> rendering context is created and attached to the entire client area of the window. When the window is closed, the OpenGL<sup>®</sup> rendering context is detached and destroyed.

Through a window it is possible to receive user input in the form of keyboard and mouse input. User input is exposed through the GLFW API primarily via a set of callback functions. Also, GLFW stores most user input as internal state that can be queried through different GLFW API functions (for instance it is possible to query the position of the mouse cursor with the **glfwGetMousePos** function).

As for user input, it is possible to receive information about window state changes, such as window resize or close events, through callback functions. It is also possible to query some kinds of information about the window information using GLFW API functions.

### 2.2 The GLFW Event Loop

The GLFW event loop is an open loop, which means that it is up to the programmer to design the loop. Events are processed by calling specific GLFW functions, which in turn query the system for new input and window events and reports these events back to the program through callback functions.

The programmer decides when to call the event processing functions and when to abort the event loop.

In pseudo language, a typical event loop might look like this:



```
repeat until window is closed
{
    poll events
    draw OpenGL graphics
}
```

There are two ways to handle events in GLFW:

- Block the event loop while waiting for new events.
- Poll for new events and continue the loop regardless of whether there are any new events or not.

The first method is useful for interactive applications that do not need to refresh the OpenGL<sup>®</sup> display unless the user interacts with the application through user input. Typical applications are CAD software and other kinds of editors.

The second method is useful for applications that need to refresh the OpenGL<sup>®</sup> display constantly, regardless of user input, such as games, demos, 3D animations, screen savers and so on.

## 2.3 Callback Functions

Using callback functions can be a good method for receiving up to date information about window state and user input. When a window has been opened, it is possible to register custom callback functions that will be called when certain events occur.

Callback functions are called from any of the event polling functions **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers**.

Callback functions should *only* be used to gather information. Since the callback functions are called from within the internal GLFW event polling loops, they should not call any GLFW functions that might result in considerable GLFW state changes, nor stall the event polling loop for a lengthy period of time.

In other words, most or all OpenGL<sup>®</sup> rendering should be called from the main application event loop, not from any of the GLFW callback functions. Also, the only GLFW functions that may be safely called from callback functions are the different Get functions (e.g. **glfwGetKey**, **glfwGetTime**, **glfwGetWindowParam** etc.).

## 2.4 Threads

GLFW has functions for creating threads, which means that it is possible to make multi-threaded applications with GLFW. It is recommended that all OpenGL<sup>®</sup> functions and all GLFW functions except those relating to threading and time are called only from the main thread, i.e. the one from which

**main** is called. Additional threads should primarily be used for CPU heavy tasks or for managing other resources such as file or sound I/O.

It should be noted that the current implementation of GLFW is not thread safe, so you should never call GLFW functions from different threads. <sup>1</sup>

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<sup>1</sup>The thread management functions are of course thread safe.

## Chapter 3

# Function Reference

### 3.1 GLFW Initialization and Termination

Before any other GLFW functions can be used, GLFW must be initialized to ensure proper functionality, and before a program terminates GLFW should be terminated in order to free allocated resources, memory, etc.

#### 3.1.1 glfwInit

##### C language syntax

```
int glfwInit( void )
```

##### Parameters

none

##### Return values

If the function succeeds, GL\_TRUE is returned.

If the function fails, GL\_FALSE is returned.

##### Description

The glfwInit function initializes GLFW. No other GLFW functions may be called before this function has succeeded.

### Notes

This function may take several seconds to complete on some systems, while on other systems it may take only a fraction of a second to complete.

This function registers a function calling **glfwTerminate** with the atexit facility of the C library.

If GLFW is initialized already, this function returns GL\_TRUE immediately without affecting state.

On Mac OS X, this function will change the current directory of the application to the **Contents/Resources** subdirectory of the application's bundle, if present. For more information on bundles, see the Bundle Programming Guide provided by Apple.

## 3.1.2 glfwTerminate

### C language syntax

```
void glfwTerminate( void )
```

### Parameters

none

### Return values

none

### Description

This function terminates GLFW. Among other things it closes the window, if open, and kills any running threads. This function should be called before a program exits.

## 3.1.3 glfwGetVersion

### C language syntax

```
void glfwGetVersion( int *major, int *minor, int *rev )
```

### Parameters

#### *major*

Pointer to an integer that will hold the major version number.

#### *minor*

Pointer to an integer that will hold the minor version number.

#### *rev*

Pointer to an integer that will hold the revision.

**Return values**

The function returns the major and minor version numbers and the revision for the currently linked GLFW library.

**Description**

This function returns the GLFW library version.

## 3.2 Window Handling

The primary purpose of GLFW is to provide a simple interface to OpenGL<sup>®</sup> context creation and window management. GLFW supports one window at a time, which can be either a normal desktop window or a fullscreen window.

### 3.2.1 glfwOpenWindow

#### C language syntax

```
int glfwOpenWindow( int width, int height, int redbits,
                   int greenbits, int bluebits, int alphabits, int depthbits,
                   int stencilbits, int mode )
```

#### Parameters

##### *width*

The width of the window. If *width* is zero, it will be calculated as  $width = \frac{4}{3}height$ , if *height* is not zero. If both *width* and *height* are zero, *width* will be set to 640.

##### *height*

The height of the window. If *height* is zero, it will be calculated as  $height = \frac{3}{4}width$ , if *width* is not zero. If both *width* and *height* are zero, *height* will be set to 480.

##### *redbits, greenbits, bluebits*

The number of bits to use for each color component of the color buffer (0 means default color depth). For instance, setting *redbits*=5, *greenbits*=6 and *bluebits*=5 will create a 16-bit color buffer, if possible.

##### *alphabits*

The number of bits to use for the alpha channel of the color buffer (0 means no alpha channel).

##### *depthbits*

The number of bits to use for the depth buffer (0 means no depth buffer).

##### *stencilbits*

The number of bits to use for the stencil buffer (0 means no stencil buffer).

##### *mode*

Selects which type of OpenGL<sup>®</sup> window to use. *mode* must be either GLFW\_WINDOW, which will generate a normal desktop window, or GLFW\_FULLSCREEN, which will generate a window which covers the entire screen. When GLFW\_FULLSCREEN is selected, the video mode will be changed to the resolution that closest matches the *width* and *height* parameters.

**Return values**

If the function succeeds, `GL_TRUE` is returned.

If the function fails, `GL_FALSE` is returned.

**Description**

This function opens a window that best matches the parameters given to the function. How well the resulting window matches the desired window depends mostly on the available hardware and OpenGL<sup>®</sup> drivers. In general, selecting a fullscreen mode has better chances of generating a close match of buffers and channel sizes than does a normal desktop window, since GLFW can freely select from all the available video modes. A desktop window is normally restricted to the video mode of the desktop.

**Notes**

For additional control of window properties, see **glfwOpenWindowHint**.

In fullscreen mode the mouse cursor is hidden by default and the screensaver is prohibited from starting. In windowed mode the mouse cursor is visible and screensavers are allowed to start. To change the visibility of the mouse cursor, use **glfwEnable** or **glfwDisable** with the argument `GLFW_MOUSE_CURSOR`.

In order to determine the actual properties of an opened window, use **glfwGetWindowParam** and **glfwGetWindowSize** (or **glfwSetWindowSizeCallback**).

On Microsoft Windows, if the executable has an icon resource named `GLFW_ICON`, it will be set as the icon for the window. If no such icon is present, the `IDI_WINLOGO` icon will be used instead.

On Mac OS X the GLFW window has no icon, but programs using GLFW will use the application bundle's icon. Also, the first time a window is opened the menu bar is populated with common commands like Hide, Quit and About. The (minimal) about dialog uses information from the application's bundle. For more information on bundles, see the Bundle Programming Guide provided by Apple.

For information on how the availability of different platform-specific extensions affect the behavior of this function, see appendix [A](#).

### 3.2.2 glfwOpenWindowHint

**C language syntax**

```
void glfwOpenWindowHint( int target, int hint )
```

Name	Default	Description
GLFW_REFRESH_RATE	0	Vertical monitor refresh rate in Hz (only used for fullscreen windows). Zero means system default.
GLFW_ACCUM_RED_BITS	0	Number of bits for the red channel of the accumulation buffer.
GLFW_ACCUM_GREEN_BITS	0	Number of bits for the green channel of the accumulation buffer.
GLFW_ACCUM_BLUE_BITS	0	Number of bits for the blue channel of the accumulation buffer.
GLFW_ACCUM_ALPHA_BITS	0	Number of bits for the alpha channel of the accumulation buffer.
GLFW_AUX_BUFFERS	0	Number of auxiliary buffers.
GLFW_STEREO	GL_FALSE	Specify if stereo rendering should be supported (can be GL_TRUE or GL_FALSE).
GLFW_WINDOW_NO_RESIZE	GL_FALSE	Specify whether the window can be resized by the user (not used for fullscreen windows).
GLFW_FSAA_SAMPLES	0	Number of samples to use for the multisampling buffer. Zero disables multisampling.
GLFW_OPENGL_VERSION_MAJOR	1	Major number of the desired minimum OpenGL <sup>®</sup> version.
GLFW_OPENGL_VERSION_MINOR	0	Minor number of the desired minimum OpenGL <sup>®</sup> version.
GLFW_OPENGL_FORWARD_COMPAT	GL_FALSE	Specify whether the OpenGL <sup>®</sup> context should be forward-compatible (i.e. disallow legacy functionality). This should only be used when requesting OpenGL <sup>®</sup> version 3.0 or above.
GLFW_OPENGL_DEBUG_CONTEXT	GL_FALSE	Specify whether a debug context should be created.
GLFW_OPENGL_PROFILE	0	The OpenGL <sup>®</sup> profile the context should implement, or zero to let the system choose. Available profiles are GLFW_OPENGL_CORE_PROFILE and GLFW_OPENGL_COMPAT_PROFILE.

Table 3.1: Targets for **glfwOpenWindowHint**



## Parameters

### *target*

Can be any of the tokens in the table 3.1.

### *hint*

An integer giving the value of the corresponding token (see table 3.1).

## Return values

none

## Description

This function sets additional properties for a window that is to be opened. For a hint to take effect, it must be set *before* calling **glfwOpenWindow**. When **glfwOpenWindow** is called, regardless of whether it succeeds, all window hints are reset to their default values.

## Notes

All window hints are reset to their default values by each successful call to **glfwInit** and by each call to **glfwOpenWindow**, whether successful or not.

In order to determine the actual properties of an opened window, use **glfwGetWindowParam** (after the window has been opened).

GLFW\_STEREO is a hard constraint. If stereo rendering is requested, but no stereo rendering capable pixel formats / framebuffer configs are available, **glfwOpenWindow** will fail.

The GLFW\_REFRESH\_RATE hint should be used with caution. Most systems have default values for monitor refresh rates that are optimal for the specific system. Specifying the refresh rate can override these settings, which can result in suboptimal operation. The monitor may be unable to display the resulting video signal, or in the worst case it may even be damaged!

The GLFW\_WINDOW\_NO\_RESIZE hint applies only to manual resizing by the user. A window created with this hint enabled can still be resized by the application by calling **glfwSetWindowSize**.

The GLFW\_OPENGL\_VERSION\_MAJOR and GLFW\_OPENGL\_VERSION\_MINOR hints specify the OpenGL<sup>®</sup> version that the created context must be compatible with, *not* the exact version to use. It is therefore perfectly safe to use the default of version 1.0 for legacy code and you will still get backwards-compatible contexts of version 3.0 and above when available.

To make the behavior of the above version hints consistent across both modern and legacy drivers, **glfwOpenWindow** will fail if the modern creation mechanism (as specified in **WGL\_ARB\_create\_context** and **GLX\_ARB\_create\_context**) is unavailable *and* the created context is of a version lower than the one that was requested.

At the time of release, the exact meaning of what a "debug context" is (as created using the GLFW\_OPENGL\_DEBUG\_CONTEXT hint) has yet to be defined by the Khronos ARB WG.

For information on how the availability of different extensions affect the behavior of this function, see appendix [A](#).

For full details on the workings of the OpenGL<sup>®</sup> version, forward-compatibility and debug hints, see the specifications for **WGL\_ARB\_create\_context** and **GLX\_ARB\_create\_context**, respectively. The relevant GLFW hints map very closely to their platform-specific counterparts.

### 3.2.3 glfwCloseWindow

#### C language syntax

```
void glfwCloseWindow( void )
```

#### Parameters

none

#### Return values

none

#### Description

This function closes an opened window and destroys the associated OpenGL<sup>®</sup> context.

### 3.2.4 glfwSetWindowCloseCallback

#### C language syntax

```
void glfwSetWindowCloseCallback( GLFWwindowclosefun cbfun )
```

#### Parameters

##### *cbfun*

Pointer to a callback function that will be called when a user requests that the window should be closed, typically by clicking the window close icon (e.g. the cross in the upper right corner of a window under Microsoft Windows), and on Mac OS X also when selecting **Quit** from the application menu. The function should have the following C language prototype:

```
int GLFWCALL functionname( void );
```

Where *functionname* is the name of the callback function. The return value of the callback function indicates whether or not the window close action should continue. If the function returns GL\_TRUE, the window will be closed. If the function returns GL\_FALSE, the window will not be closed.

If *cbfun* is NULL, any previously set callback function will be unset.

**Return values**

none

**Description**

This function sets the callback for window close events.

A window has to be opened for this function to have any effect.

**Notes**

Window close events are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

The OpenGL<sup>®</sup> context is still valid when this function is called.

Note that the window close callback function is not called when **glfwCloseWindow** is called, but only when the close request comes from the window manager.

Do *not* call **glfwCloseWindow** from a window close callback function. Close the window by returning `GL_TRUE` from the function.

### 3.2.5 glfwSetWindowTitle

**C language syntax**

```
void glfwSetWindowTitle( const char *title )
```

**Parameters*****title***

Pointer to a null terminated ISO 8859-1 (8-bit Latin 1) string that holds the title of the window.

**Return values**

none

**Description**

This function changes the title of the opened window.

**Notes**

The title property of a window is often used in situations other than for the window title, such as the title of an application icon when it is in iconified state.

### 3.2.6 glfwSetWindowSize

#### C language syntax

```
void glfwSetWindowSize( int width, int height )
```

#### Parameters

***width***

Width of the window.

***height***

Height of the window.

#### Return values

none

#### Description

This function changes the size of an opened window. The *width* and *height* parameters denote the size of the client area of the window (i.e. excluding any window borders and decorations).

If the window is in fullscreen mode, the video mode will be changed to a resolution that closest matches the width and height parameters (the number of color bits will not be changed).

#### Notes

This function has no effect if the window is iconified.

The OpenGL<sup>®</sup> context is guaranteed to be preserved after calling **glfwSetWindowSize**, even if the video mode is changed.

This function is not affected by the value of the GLFW\_WINDOW\_NO\_RESIZE hint.

### 3.2.7 glfwSetWindowPos

#### C language syntax

```
void glfwSetWindowPos( int x, int y )
```

#### Parameters

***x***

Horizontal position of the window, relative to the upper left corner of the desktop.

***y***

Vertical position of the window, relative to the upper left corner of the desktop.

**Return values**

none

**Description**

This function changes the position of an opened window. It does not have any effect on a fullscreen window.

**Notes**

This function has no effect if the window is iconified.

The behaviour of this function on multi-monitor systems is ill-defined.

### 3.2.8 glfwGetWindowSize

**C language syntax**

```
void glfwGetWindowSize( int *width, int *height )
```

**Parameters*****width***

Pointer to an integer that will hold the width of the window.

***height***

Pointer to an integer that will hold the height of the window.

**Return values**

The current width and height of the opened window is returned in the *width* and *height* parameters, respectively.

**Description**

This function is used for determining the size of an opened window. The returned values are dimensions of the client area of the window (i.e. excluding any window borders and decorations).

**Notes**

Even if the size of a fullscreen window does not change once the window has been opened, it does not necessarily have to be the same as the size that was requested using **glfwOpenWindow**. Therefore it is wise to use this function to determine the true size of the window once it has been opened.

### 3.2.9 glfwSetWindowSizeCallback

#### C language syntax

```
void glfwSetWindowSizeCallback( GLFWwintowsizefun cbfun )
```

#### Parameters

##### *cbfun*

Pointer to a callback function that will be called every time the window size changes. The function should have the following C language prototype:

```
void GLFWCALL functionname( int width, int height );
```

Where *functionname* is the name of the callback function, and *width* and *height* are the dimensions of the window client area.

If *cbfun* is NULL, any previously set callback function will be unset.

#### Return values

none

#### Description

This function sets the callback for window size change events.

A window has to be opened for this function to have any effect.

#### Notes

Window size changes are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

When a callback function is set, it will be called with the current window size before this function returns.

### 3.2.10 glfwIconifyWindow

#### C language syntax

```
void glfwIconifyWindow( void )
```

#### Parameters

none

**Return values**

none

**Description**

Iconify a window. If the window is in fullscreen mode, then the desktop video mode will be restored.

### 3.2.11 glfwRestoreWindow

**C language syntax**

```
void glfwRestoreWindow( void )
```

**Parameters**

none

**Return values**

none

**Description**

Restore an iconified window. If the window that is restored is in fullscreen mode, then the fullscreen video mode will be restored.

### 3.2.12 glfwGetWindowParam

**C language syntax**

```
int glfwGetWindowParam( int param )
```

**Parameters**

*param*

A token selecting which parameter the function should return (see table 3.2).

**Return values**

The function returns the value the window parameter corresponding to the token *param*. Table 3.2 lists the available tokens.

**Description**

This function is used for acquiring various properties of an opened window.

Name	Description
GLFW_OPENED	GL_TRUE if window is opened, else GL_FALSE.
GLFW_ACTIVE	GL_TRUE if window has focus, else GL_FALSE.
GLFW_ICONIFIED	GL_TRUE if window is iconified, else GL_FALSE.
GLFW_ACCELERATED	GL_TRUE if window is hardware accelerated, else GL_FALSE.
GLFW_RED_BITS	Number of bits for the red color component.
GLFW_GREEN_BITS	Number of bits for the green color component.
GLFW_BLUE_BITS	Number of bits for the blue color component.
GLFW_ALPHA_BITS	Number of bits for the alpha buffer.
GLFW_DEPTH_BITS	Number of bits for the depth buffer.
GLFW_STENCIL_BITS	Number of bits for the stencil buffer.
GLFW_REFRESH_RATE	Vertical monitor refresh rate in Hz. Zero indicates an unknown or a default refresh rate.
GLFW_ACCUM_RED_BITS	Number of bits for the red channel of the accumulation buffer.
GLFW_ACCUM_GREEN_BITS	Number of bits for the green channel of the accumulation buffer.
GLFW_ACCUM_BLUE_BITS	Number of bits for the blue channel of the accumulation buffer.
GLFW_ACCUM_ALPHA_BITS	Number of bits for the alpha channel of the accumulation buffer.
GLFW_AUX_BUFFERS	Number of auxiliary buffers.
GLFW_STEREO	GL_TRUE if stereo rendering is supported, else GL_FALSE.
GLFW_WINDOW_NO_RESIZE	GL_TRUE if the window cannot be resized by the user, else GL_FALSE.
GLFW_FSAA_SAMPLES	Number of multisampling buffer samples. Zero indicated multisampling is disabled.
GLFW_OPENGL_VERSION_MAJOR	Major number of the actual version of the context.
GLFW_OPENGL_VERSION_MINOR	Minor number of the actual version of the context.
GLFW_OPENGL_FORWARD_COMPAT	GL_TRUE if the context is forward-compatible, else GL_FALSE.
GLFW_OPENGL_DEBUG_CONTEXT	GL_TRUE if the context is a debug context.
GLFW_OPENGL_PROFILE	The profile implemented by the context, or zero.

Table 3.2: Window parameters for **glfwGetWindowParam**



**Notes**

GLFW\_ACCELERATED is only supported under Windows. Other systems will always return GL\_TRUE. Under Windows, GLFW\_ACCELERATED means that the OpenGL<sup>®</sup> renderer is a 3rd party renderer, rather than the fallback Microsoft software OpenGL<sup>®</sup> renderer. In other words, it is not a real guarantee that the OpenGL<sup>®</sup> renderer is actually hardware accelerated.

GLFW\_OPENGL\_VERSION\_MAJOR and GLFW\_OPENGL\_VERSION\_MINOR always return the same values as those returned by **glfwGetGLVersion**.

### 3.2.13 glfwSwapBuffers

**C language syntax**

```
void glfwSwapBuffers( void )
```

**Parameters**

none

**Return values**

none

**Description**

This function swaps the back and front color buffers of the window. If GLFW\_AUTO\_POLL\_EVENTS is enabled (which is the default), **glfwPollEvents** is called after swapping the front and back buffers.

**Notes**

In previous versions of GLFW, **glfwPollEvents** was called *before* buffer swap. This was changed in order to decrease input lag but may affect code that relied on the former behavior.

### 3.2.14 glfwSwapInterval

**C language syntax**

```
void glfwSwapInterval( int interval )
```

**Parameters*****interval***

Minimum number of monitor vertical retraces between each buffer swap performed by **glfwSwapBuffers**. If *interval* is zero, buffer swaps will not be synchronized to the vertical refresh of the monitor (also known as 'VSync off').

**Return values**

none

**Description**

This function selects the minimum number of monitor vertical retraces that should occur between two buffer swaps. If the selected swap interval is one, the rate of buffer swaps will never be higher than the vertical refresh rate of the monitor. If the selected swap interval is zero, the rate of buffer swaps is only limited by the speed of the software and the hardware.

**Notes**

This function will only have an effect on hardware and drivers that support user selection of the swap interval. ATI drivers in particular have been known to ignore this setting.

### 3.2.15 glfwSetWindowRefreshCallback

**C language syntax**

```
void glfwSetWindowRefreshCallback( GLFWwindowrefreshfun cbfun )
```

**Parameters*****cbfun***

Pointer to a callback function that will be called when the window client area needs to be refreshed. The function should have the following C language prototype:

```
void GLFWCALL functionname( void );
```

Where *functionname* is the name of the callback function.

If *cbfun* is NULL, any previously set callback function will be unset.

**Return values**

none

**Description**

This function sets the callback for window refresh events, which occurs when any part of the window client area has been damaged, and needs to be repainted (for instance, if a part of the window that was previously occluded by another window has become visible).

A window has to be opened for this function to have any effect.

**Notes**

Window refresh events are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

Modern windowing systems using hardware compositing, such as Aqua, Aero and Compiz, very rarely need to refresh the contents of windows, so the specified callback will very rarely be called on such systems.

## 3.3 Video Modes

Since GLFW supports video mode changes when using a fullscreen window, it also provides functionality for querying which video modes are supported on a system.

### 3.3.1 glfwGetVideoModes

#### C language syntax

```
int glfwGetVideoModes( GLFWvidmode *list, int maxcount )
```

#### Parameters

*list*

A vector of *GLFWvidmode* structures, which will be filled out by the function.

*maxcount*

Maximum number of video modes that *list* vector can hold.

#### Return values

The function returns the number of detected video modes (this number will never exceed *maxcount*). The *list* vector is filled out with the video modes that are supported by the system.

#### Description

This function returns a list of supported video modes. Each video mode is represented by a *GLFWvidmode* structure, which has the following definition:

```
typedef struct {  
    int Width, Height; // Video resolution  
    int RedBits;       // Number of red bits  
    int GreenBits;     // Number of green bits  
    int BlueBits;      // Number of blue bits  
} GLFWvidmode;
```

#### Notes

The returned list is sorted, first by color depth (*RedBits* + *GreenBits* + *BlueBits*), and then by resolution (*Width* × *Height*), with the lowest resolution, fewest bits per pixel mode first.

### 3.3.2 glfwGetDesktopMode

#### C language syntax

```
void glfwGetDesktopMode( GLFWvidmode *mode )
```

#### Parameters

##### *mode*

Pointer to a *GLFWvidmode* structure, which will be filled out by the function.

#### Return values

The *GLFWvidmode* structure pointed to by *mode* is filled out with the desktop video mode.

#### Description

This function returns the desktop video mode in a *GLFWvidmode* structure. See **glfwGetVideoModes** for a definition of the *GLFWvidmode* structure.

#### Notes

The color depth of the desktop display is always reported as the number of bits for each individual color component (red, green and blue), even if the desktop is not using an RGB or RGBA color format. For instance, an indexed 256 color display may report *RedBits* = 3, *GreenBits* = 3 and *BlueBits* = 2, which adds up to 8 bits in total.

The desktop video mode is the video mode used by the desktop at the time the GLFW window was opened, *not* the current video mode (which may differ from the desktop video mode if the GLFW window is a fullscreen window).

## 3.4 Input Handling

GLFW supports three channels of user input: keyboard input, mouse input and joystick input.

Keyboard and mouse input can be treated either as events, using callback functions, or as state, using functions for polling specific keyboard and mouse states. Regardless of which method is used, all keyboard and mouse input is collected using window event polling.

Joystick input is asynchronous to the keyboard and mouse input, and does not require event polling for keeping up to date joystick information. Also, joystick input is independent of any window, so a window does not have to be opened for joystick input to be used.

### 3.4.1 glfwPollEvents

#### C language syntax

```
void glfwPollEvents( void )
```

#### Parameters

none

#### Return values

none

#### Description

This function is used for polling for events, such as user input and window resize events. Upon calling this function, all window states, keyboard states and mouse states are updated. If any related callback functions are registered, these are called during the call to **glfwPollEvents**.

#### Notes

**glfwPollEvents** is called implicitly from **glfwSwapBuffers** if **GLFW\_AUTO\_POLL\_EVENTS** is enabled (as it is by default). Thus, if **glfwSwapBuffers** is called frequently, which is normally the case, there is no need to call **glfwPollEvents**.

### 3.4.2 glfwWaitEvents

#### C language syntax

```
void glfwWaitEvents( void )
```

**Parameters**

none

**Return values**

none

**Description**

This function is used for waiting for events, such as user input and window resize events. Upon calling this function, the calling thread will be put to sleep until any event appears in the event queue. When events are available, they will be processed just as they are processed by **glfwPollEvents**.

If there are any events in the queue when the function is called, the function will behave exactly like **glfwPollEvents** (i.e. process all messages and then return, without blocking the calling thread).

**Notes**

It is guaranteed that **glfwWaitEvents** will wake up on any event that can be processed by **glfwPollEvents**. However, GLFW receives many events that are only processed internally and the function may behave differently on different systems. Do not make any assumptions about when or why **glfwWaitEvents** will return.

### 3.4.3 glfwGetKey

**C language syntax**

```
int glfwGetKey( int key )
```

**Parameters***key*

A keyboard key identifier, which can be either an uppercase printable ISO 8859-1 (Latin 1) character (e.g. 'A', '3' or '.'), or a special key identifier. Table 3.3 lists valid special key identifiers.

**Return values**

The function returns `GLFW_PRESS` if the key is held down, or `GLFW_RELEASE` if the key is not held down.

**Description**

This function queries the current state of a specific keyboard key. The physical location of each key depends on the system keyboard layout setting.

Name	Description
GLFW_KEY_SPACE	Space
GLFW_KEY_ESC	Escape
GLFW_KEY_Fn	Function key <i>n</i> ( <i>n</i> can be in the range 1..25)
GLFW_KEY_UP	Cursor up
GLFW_KEY_DOWN	Cursor down
GLFW_KEY_LEFT	Cursor left
GLFW_KEY_RIGHT	Cursor right
GLFW_KEY_LSHIFT	Left shift key
GLFW_KEY_RSHIFT	Right shift key
GLFW_KEY_LCTRL	Left control key
GLFW_KEY_RCTRL	Right control key
GLFW_KEY_LALT	Left alternate function key
GLFW_KEY_RALT	Right alternate function key
GLFW_KEY_LSUPER	Left super key, WinKey, or command key
GLFW_KEY_RSUPER	Right super key, WinKey, or command key
GLFW_KEY_TAB	Tabulator
GLFW_KEY_ENTER	Enter
GLFW_KEY_BACKSPACE	Backspace
GLFW_KEY_INSERT	Insert
GLFW_KEY_DEL	Delete
GLFW_KEY_PAGEUP	Page up
GLFW_KEY_PAGEDOWN	Page down
GLFW_KEY_HOME	Home
GLFW_KEY_END	End
GLFW_KEY_KP_0	Keypad numeric key <i>n</i> ( <i>n</i> can be in the range 0..9)
GLFW_KEY_KP_DIVIDE	Keypad divide (÷)
GLFW_KEY_KP_MULTIPLY	Keypad multiply (×)
GLFW_KEY_KP_SUBTRACT	Keypad subtract (−)
GLFW_KEY_KP_ADD	Keypad add (+)
GLFW_KEY_KP_DECIMAL	Keypad decimal (. or ,)
GLFW_KEY_KP_EQUAL	Keypad equal (=)
GLFW_KEY_KP_ENTER	Keypad enter
GLFW_KEY_KP_NUM_LOCK	Keypad num lock
GLFW_KEY_CAPS_LOCK	Caps lock
GLFW_KEY_SCROLL_LOCK	Scroll lock
GLFW_KEY_PAUSE	Pause key
GLFW_KEY_MENU	Menu key

Table 3.3: Special key identifiers



## Notes

The constant `GLFW_KEY_SPACE` is equal to 32, which is the ISO 8859-1 code for space. This is the only named GLFW key identifier with a value in the ISO 8859-1 range.

Not all key codes are supported on all systems. Also, while some keys are available on some keyboard layouts, they may not be available on other keyboard layouts.

For systems that do not distinguish between left and right versions of modifier keys (shift, alt and control), the left version is used (e.g. `GLFW_KEY_LSHIFT`).

A window must be opened for the function to have any effect, and **`glfwPollEvents`**, **`glfwWaitEvents`** or **`glfwSwapBuffers`** (with `GLFW_AUTO_POLL_EVENTS` enabled) must be called before any keyboard events are recorded and reported by **`glfwGetKey`**.

## 3.4.4 `glfwGetMouseButton`

### C language syntax

```
int glfwGetMouseButton( int button )
```

### Parameters

#### *button*

A mouse button identifier, which can be one of the mouse button identifiers listed in table 3.4.

### Return values

The function returns `GLFW_PRESS` if the mouse button is held down, or `GLFW_RELEASE` if the mouse button is not held down.

### Description

This function queries the current state of a specific mouse button.

## Notes

A window must be opened for the function to have any effect, and **`glfwPollEvents`**, **`glfwWaitEvents`** or **`glfwSwapBuffers`** (with `GLFW_AUTO_POLL_EVENTS` enabled) must be called before any mouse button events are recorded and reported by **`glfwGetMouseButton`**.

`GLFW_MOUSE_BUTTON_LEFT` is equal to `GLFW_MOUSE_BUTTON_1`.

`GLFW_MOUSE_BUTTON_RIGHT` is equal to `GLFW_MOUSE_BUTTON_2`.

`GLFW_MOUSE_BUTTON_MIDDLE` is equal to `GLFW_MOUSE_BUTTON_3`.

### 3.4.5 glfwGetMousePos

#### C language syntax

```
void glfwGetMousePos( int *xpos, int *ypos )
```

#### Parameters

*xpos*

Pointer to an integer that will be set to the horizontal position of the mouse cursor.

*ypos*

Pointer to an integer that will be set to the vertical position of the mouse cursor.

#### Return values

The function returns the current mouse cursor position in *xpos* and *ypos*.

#### Description

This function returns the current mouse position. If the cursor is not hidden, the mouse position is the cursor position, relative to the upper left corner of the window and with the Y-axis down. If the cursor is hidden, the mouse position is a virtual absolute position, not limited to any boundaries except to those implied by the maximum number that can be represented by a signed integer.

#### Notes

A window must be opened for the function to have any effect, and **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) must be called before any mouse movements are recorded and reported by **glfwGetMousePos**.

### 3.4.6 glfwSetMousePos

#### C language syntax

```
void glfwSetMousePos( int xpos, int ypos )
```

#### Parameters

*xpos*

Horizontal position of the mouse.

*ypos*

Vertical position of the mouse.

**Return values**

none

**Description**

This function changes the position of the mouse. If the cursor is visible (not disabled), the cursor will be moved to the specified position, relative to the upper left corner of the window client area and with the Y-axis down. If the cursor is hidden (disabled), only the mouse position that is reported by GLFW is changed.

### 3.4.7 glfwGetMouseWheel

**C language syntax**

```
int glfwGetMouseWheel( void )
```

**Parameters**

none

**Return values**

The function returns the current mouse wheel position.

**Description**

This function returns the current mouse wheel position. The mouse wheel can be thought of as a third mouse axis, which is available as a separate wheel or up/down stick on some mice.

**Notes**

A window must be opened for the function to have any effect, and **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) must be called before any mouse wheel movements are recorded and reported by **glfwGetMouseWheel**.

### 3.4.8 glfwSetMouseWheel

**C language syntax**

```
void glfwSetMouseWheel( int pos )
```

**Parameters**

*pos*

Position of the mouse wheel.

**Return values**

none

**Description**

This function changes the position of the mouse wheel.

### 3.4.9 glfwSetKeyCallback

**C language syntax**

```
void glfwSetKeyCallback( GLFWkeyfun cbfun )
```

**Parameters*****cbfun***

Pointer to a callback function that will be called every time a key is pressed or released. The function should have the following C language prototype:

```
void GLFWCALL functionname( int key, int action );
```

Where *functionname* is the name of the callback function, *key* is a key identifier, which is an uppercase printable ISO 8859-1 character or a special key identifier (see table 3.3), and *action* is either `GLFW_PRESS` or `GLFW_RELEASE`.

If *cbfun* is `NULL`, any previously set callback function will be unset.

**Return values**

none

**Description**

This function sets the callback for keyboard key events. The callback function is called every time the state of a single key is changed (from released to pressed or vice versa). The reported keys are unaffected by any modifiers (such as shift or alt) and each modifier is reported as a separate key.

A window has to be opened for this function to have any effect.

**Notes**

Keyboard key events are not intended for text input and many languages will not be able to be input using it. Use Unicode character events for text input instead.

Keyboard events are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

### 3.4.10 glfwSetCharCallback

#### C language syntax

```
void glfwSetCharCallback( GLFWcharfun cbfun )
```

#### Parameters

##### *cbfun*

Pointer to a callback function that will be called every time a printable character is generated by the keyboard. The function should have the following C language prototype:

```
void GLFWCALL functionname( int character, int action );
```

Where *functionname* is the name of the callback function, *character* is a Unicode (ISO 10646) character, and *action* is either `GLFW_PRESS` or `GLFW_RELEASE`.

If *cbfun* is `NULL`, any previously set callback function will be unset.

#### Return values

none

#### Description

This function sets the callback for keyboard character events. The callback function is called every time a key that results in a printable Unicode character is pressed or released. Characters are affected by modifiers (such as shift or alt).

A window has to be opened for this function to have any effect.

#### Notes

Character events are recorded continuously, but only reported when `glfwPollEvents`, `glfwWaitEvents` or `glfwSwapBuffers` (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

Control characters such as tab and carriage return are not reported to the character callback function, since they are not part of the Unicode character set. Use the key callback function for such events (see `glfwSetKeyCallback`).

The Unicode character set supports character codes above 255, so never cast a Unicode character to an eight bit data type (e.g. the C language 'char' type) without first checking that the character code is less than 256. Also note that Unicode character codes 0 to 255 are equal to ISO 8859-1 (Latin 1).

### 3.4.11 glfwSetMouseButtonCallback

#### C language syntax

```
void glfwSetMouseButtonCallback( GLFWmousebuttonfun cbfun )
```

### Parameters

#### *cbfun*

Pointer to a callback function that will be called every time a mouse button is pressed or released. The function should have the following C language prototype:

```
void GLFWCALL functionname( int button, int action );
```

Where *functionname* is the name of the callback function, *button* is a mouse button identifier (see table 3.4 on page 42), and *action* is either `GLFW_PRESS` or `GLFW_RELEASE`.

If *cbfun* is `NULL`, any previously set callback function will be unset.

### Return values

none

### Description

This function sets the callback for mouse button events.

A window has to be opened for this function to have any effect.

### Notes

Mouse button events are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

`GLFW_MOUSE_BUTTON_LEFT` is equal to `GLFW_MOUSE_BUTTON_1`.

`GLFW_MOUSE_BUTTON_RIGHT` is equal to `GLFW_MOUSE_BUTTON_2`.

`GLFW_MOUSE_BUTTON_MIDDLE` is equal to `GLFW_MOUSE_BUTTON_3`.

## 3.4.12 glfwSetMousePosCallback

### C language syntax

```
void glfwSetMousePosCallback( GLFWmouseposfun cbfun )
```

### Parameters

#### *cbfun*

Pointer to a callback function that will be called every time the mouse is moved. The function should have the following C language prototype:

```
void GLFWCALL functionname( int x, int y );
```

Where *functionname* is the name of the callback function, and *x* and *y* are the mouse coordinates (see **glfwGetMousePos** for more information on mouse coordinates).

If *cbfun* is NULL, any previously set callback function will be unset.

**Return values**

none

**Description**

This function sets the callback for mouse motion events.

A window has to be opened for this function to have any effect.

**Notes**

Mouse motion events are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with GLFW\_AUTO\_POLL\_EVENTS enabled) is called.

When a callback function is set, it will be called with the current mouse coordinates before this function returns.

### 3.4.13 glfwSetMouseWheelCallback

**C language syntax**

```
void glfwSetMouseWheelCallback( GLFWmousewheelfun cbfun )
```

**Parameters*****cbfun***

Pointer to a callback function that will be called every time the mouse wheel is moved. The function should have the following C language prototype:

```
void GLFWCALL functionname( int pos );
```

Where *functionname* is the name of the callback function, and *pos* is the mouse wheel position.

If *cbfun* is NULL, any previously set callback function will be unset.

**Return values**

none

**Description**

This function sets the callback for mouse wheel events.

A window has to be opened for this function to have any effect.

**Notes**

Mouse wheel events are recorded continuously, but only reported when **glfwPollEvents**, **glfwWaitEvents** or **glfwSwapBuffers** (with `GLFW_AUTO_POLL_EVENTS` enabled) is called.

When a callback function is set, it will be called with the current wheel position before this function returns.

### 3.4.14 glfwGetJoystickParam

**C language syntax**

```
int glfwGetJoystickParam( int joy, int param )
```

**Parameters*****joy***

A joystick identifier, which should be `GLFW_JOYSTICK_n`, where *n* is in the range 1 to 16.

***param***

A token selecting which parameter the function should return (see table 3.5).

**Return values**

The function returns different parameters depending on the value of *param*. Table 3.5 lists valid *param* values, and their corresponding return values.

**Description**

This function is used for acquiring various properties of a joystick.

**Notes**

The joystick information is updated every time the function is called.

No window has to be opened for joystick information to be available.



### 3.4.15 glfwGetJoystickPos

#### C language syntax

```
int glfwGetJoystickPos( int joy, float *pos, int numaxes )
```

#### Parameters

***joy***

A joystick identifier, which should be `GLFW_JOYSTICK_n`, where *n* is in the range 1 to 16.

***pos***

An array that will hold the positional values for all requested axes.

***numaxes***

Specifies how many axes should be returned.

#### Return values

The function returns the number of actually returned axes. This is the minimum of *numaxes* and the number of axes supported by the joystick. If the joystick is not supported or connected, the function will return 0 (zero).

#### Description

This function queries the current position of one or more axes of a joystick. The positional values are returned in an array, where the first element represents the first axis of the joystick (normally the X axis). Each position is in the range -1.0 to 1.0. Where applicable, the positive direction of an axis is right, forward or up, and the negative direction is left, back or down.

If *numaxes* exceeds the number of axes supported by the joystick, or if the joystick is not available, the unused elements in the *pos* array will be set to 0.0 (zero).

#### Notes

The joystick state is updated every time the function is called, so there is no need to call **glfwPollEvents** or **glfwWaitEvents** for joystick state to be updated.

Use **glfwGetJoystickParam** to retrieve joystick capabilities, such as joystick availability and number of supported axes.

No window has to be opened for joystick input to be available.

### 3.4.16 glfwGetJoystickButtons

#### C language syntax

```
int glfwGetJoystickButtons( int joy, unsigned char *buttons,
                           int numbuttons )
```

### Parameters

#### *joy*

A joystick identifier, which should be `GLFW_JOYSTICK_1`, where *n* is in the range 1 to 16.

#### *buttons*

An array that will hold the button states for all requested buttons.

#### *numbuttons*

Specifies how many buttons should be returned.

### Return values

The function returns the number of actually returned buttons. This is the minimum of *numbuttons* and the number of buttons supported by the joystick. If the joystick is not supported or connected, the function will return 0 (zero).

### Description

This function queries the current state of one or more buttons of a joystick. The button states are returned in an array, where the first element represents the first button of the joystick. Each state can be either `GLFW_PRESS` or `GLFW_RELEASE`.

If *numbuttons* exceeds the number of buttons supported by the joystick, or if the joystick is not available, the unused elements in the *buttons* array will be set to `GLFW_RELEASE`.

### Notes

The joystick state is updated every time the function is called, so there is no need to call `glfwPollEvents` or `glfwWaitEvents` for joystick state to be updated.

Use `glfwGetJoystickParam` to retrieve joystick capabilities, such as joystick availability and number of supported buttons.

No window has to be opened for joystick input to be available.

## 3.5 Timing

### 3.5.1 glfwGetTime

#### C language syntax

```
double glfwGetTime( void )
```

#### Parameters

none

#### Return values

The function returns the value of the high precision timer. The time is measured in seconds, and is returned as a double precision floating point value.

#### Description

This function returns the state of a high precision timer. Unless the timer has been set by the **glfwSetTime** function, the time is measured as the number of seconds that have passed since **glfwInit** was called.

#### Notes

The resolution of the timer depends on which system the program is running on.

### 3.5.2 glfwSetTime

#### C language syntax

```
void glfwSetTime( double time )
```

#### Parameters

*time*

Time (in seconds) that the timer should be set to.

#### Return values

none

#### Description

This function sets the current time of the high precision timer to the specified time. Subsequent calls to **glfwGetTime** will be relative to this time. The time is given in seconds.

### 3.5.3 glfwSleep

#### C language syntax

```
void glfwSleep( double time )
```

#### Parameters

##### *time*

Time, in seconds, to sleep.

#### Return values

none

#### Description

This function puts the calling thread to sleep for the requested period of time. Only the calling thread is put to sleep. Other threads within the same process can still execute.

#### Notes

There is usually a system dependent minimum time for which it is possible to sleep. This time is generally in the range 1 *ms* to 20 *ms*, depending on thread scheduling time slot intervals etc. Using a shorter time as a parameter to **glfwSleep** can give one of two results: either the thread will sleep for the minimum possible sleep time, or the thread will not sleep at all (**glfwSleep** returns immediately). The latter should only happen when very short sleep times are specified, if at all.

## 3.6 Image and Texture Loading

In order to aid loading of image data into textures, GLFW has basic support for loading images from files and memory buffers.

### 3.6.1 glfwReadImage

#### C language syntax

```
int glfwReadImage( const char *name, GLFWimage *img, int flags )
```

#### Parameters

##### *name*

A null terminated ISO 8859-1 string holding the name of the file that should be read.

##### *img*

Pointer to a GLFWimage struct, which will hold the information about the loaded image (if the read was successful).

##### *flags*

Flags for controlling the image reading process. Valid flags are listed in table 3.6

#### Return values

The function returns GL\_TRUE if the image was loaded successfully. Otherwise GL\_FALSE is returned.

#### Description

This function reads an image from the file specified by the parameter *name* and returns the image information and data in a GLFWimage structure, which has the following definition:

```
typedef struct {  
    int Width, Height;      // Image dimensions  
    int Format;              // OpenGL pixel format  
    int BytesPerPixel;      // Number of bytes per pixel  
    unsigned char *Data;    // Pointer to pixel data  
} GLFWimage;
```

*Width* and *Height* give the dimensions of the image. *Format* specifies an OpenGL<sup>®</sup> pixel format, which can be GL\_LUMINANCE or GL\_ALPHA (for gray scale images), GL\_RGB or GL\_RGBA. *BytesPerPixel* specifies the number of bytes per pixel. *Data* is a pointer to the actual pixel data.

By default the read image is rescaled to the nearest larger  $2^m \times 2^n$  resolution using bilinear interpolation, if necessary, which is useful if the image is to be used as an OpenGL<sup>®</sup> texture. This behavior can be disabled by setting the GLFW\_NO\_RESCALE\_BIT flag.

Unless the flag `GLFW_ORIGIN_UL_BIT` is set, the first pixel in *img->Data* is the lower left corner of the image. If the flag `GLFW_ORIGIN_UL_BIT` is set, however, the first pixel is the upper left corner.

For single component images (i.e. gray scale), *Format* is set to `GL_ALPHA` if the flag `GLFW_ALPHA_MAP_BIT` flag is set, otherwise *Format* is set to `GL_LUMINANCE`.

#### Notes

**glfwReadImage** supports the Truevision Targa version 1 file format (.TGA). Supported pixel formats are: 8-bit gray scale, 8-bit paletted (24/32-bit color), 24-bit true color and 32-bit true color + alpha.

Paletted images are translated into true color or true color + alpha pixel formats.

### 3.6.2 glfwReadMemoryImage

#### C language syntax

```
int glfwReadMemoryImage( const void *data, long size, GLFWimage *img,
                        int flags )
```

#### Parameters

##### *data*

The memory buffer holding the contents of the file that should be read.

##### *size*

The size, in bytes, of the memory buffer.

##### *img*

Pointer to a `GLFWimage` struct, which will hold the information about the loaded image (if the read was successful).

##### *flags*

Flags for controlling the image reading process. Valid flags are listed in table [3.6](#)

#### Return values

The function returns `GL_TRUE` if the image was loaded successfully. Otherwise `GL_FALSE` is returned.

#### Description

This function reads an image file from the memory buffer specified by the parameter *data* and returns the image information and data in a `GLFWimage` structure. For more information on the GLFW image struct, see **glfwReadImage**.

**Notes**

**glfwReadMemoryImage** supports the Truevision Targa version 1 file format (.TGA). Supported pixel formats are: 8-bit gray scale, 8-bit paletted (24/32-bit color), 24-bit true color and 32-bit true color + alpha.

Paletted images are translated into true color or true color + alpha pixel formats.

### 3.6.3 glfwFreeImage

**C language syntax**

```
void glfwFreeImage( GLFWimage *img )
```

**Parameters**

*img*

Pointer to a GLFWimage struct.

**Return values**

none

**Description**

This function frees any memory occupied by a loaded image, and clears all the fields of the GLFWimage struct. Any image that has been loaded by the **glfwReadImage** function should be deallocated using this function once the image is no longer needed.

### 3.6.4 glfwLoadTexture2D

**C language syntax**

```
int glfwLoadTexture2D( const char *name, int flags )
```

**Parameters**

*name*

An ISO 8859-1 string holding the name of the file that should be loaded.

*flags*

Flags for controlling the texture loading process. Valid flags are listed in table 3.7.

Name	Description
GLFW_MOUSE_BUTTON_LEFT	Left mouse button (button 1)
GLFW_MOUSE_BUTTON_RIGHT	Right mouse button (button 2)
GLFW_MOUSE_BUTTON_MIDDLE	Middle mouse button (button 3)
GLFW_MOUSE_BUTTON_ <i>n</i>	Mouse button <i>n</i> ( <i>n</i> can be in the range 1..8)

Table 3.4: Valid mouse button identifiers

Name	Return value
GLFW_PRESENT	GL_TRUE if the joystick is connected, else GL_FALSE.
GLFW_AXES	Number of axes supported by the joystick.
GLFW_BUTTONS	Number of buttons supported by the joystick.

Table 3.5: Joystick parameters for **glfwGetJoystickParam**

Name	Description
GLFW_NO_RESCALE_BIT	Do not rescale image to closest $2^m \times 2^n$ resolution
GLFW_ORIGIN_UL_BIT	Specifies that the origin of the <i>loaded</i> image should be in the upper left corner (default is the lower left corner)
GLFW_ALPHA_MAP_BIT	Treat single component images as alpha maps rather than luminance maps

Table 3.6: Flags for functions loading image data into textures

Name	Description
GLFW_BUILD_MIPMAPS_BIT	Automatically build and upload all mipmap levels
GLFW_ORIGIN_UL_BIT	Specifies that the origin of the <i>loaded</i> image should be in the upper left corner (default is the lower left corner)
GLFW_ALPHA_MAP_BIT	Treat single component images as alpha maps rather than luminance maps

Table 3.7: Flags for **glfwLoadTexture2D**



### Return values

The function returns `GL_TRUE` if the texture was loaded successfully. Otherwise `GL_FALSE` is returned.

### Description

This function reads an image from the file specified by the parameter *name* and uploads the image to OpenGL<sup>®</sup> texture memory (using the `glTexImage2D` function).

If the `GLFW_BUILD_MIPMAPS_BIT` flag is set, all mipmap levels for the loaded texture are generated and uploaded to texture memory.

Unless the flag `GLFW_ORIGIN_UL_BIT` is set, the origin of the texture is the lower left corner of the loaded image. If the flag `GLFW_ORIGIN_UL_BIT` is set, however, the first pixel is the upper left corner.

For single component images (i.e. gray scale), the texture is uploaded as an alpha mask if the flag `GLFW_ALPHA_MAP_BIT` flag is set, otherwise it is uploaded as a luminance texture.

### Notes

`glfwLoadTexture2D` supports the Truevision Targa version 1 file format (.TGA). Supported pixel formats are: 8-bit gray scale, 8-bit paletted (24/32-bit color), 24-bit true color and 32-bit true color + alpha.

Paletted images are translated into true color or true color + alpha pixel formats.

The read texture is always rescaled to the nearest larger  $2^m \times 2^n$  resolution using bilinear interpolation, if necessary, since OpenGL<sup>®</sup> requires textures to have a  $2^m \times 2^n$  resolution.

If the `GL_SGIS_generate_mipmap` extension, which is usually hardware accelerated, is supported by the OpenGL<sup>®</sup> implementation it will be used for mipmap generation. Otherwise the mipmaps will be generated by GLFW in software.

Since OpenGL<sup>®</sup> 1.0 does not support single component alpha maps, alpha map textures are converted to RGBA format under OpenGL<sup>®</sup> 1.0 when the `GLFW_ALPHA_MAP_BIT` flag is set and the loaded texture is a single component texture. The red, green and blue components are set to 1.0.

## 3.6.5 glfwLoadMemoryTexture2D

### C language syntax

```
int glfwLoadMemoryTexture2D( const void *data, long size, int flags )
```

## Parameters

### *data*

The memory buffer holding the contents of the file that should be loaded.

### *size*

The size, in bytes, of the memory buffer.

### *flags*

Flags for controlling the texture loading process. Valid flags are listed in table 3.7.

## Return values

The function returns GL\_TRUE if the texture was loaded successfully. Otherwise GL\_FALSE is returned.

## Description

This function reads an image from the memory buffer specified by the parameter *data* and uploads the image to OpenGL<sup>®</sup> texture memory (using the **glTexImage2D** function).

If the GLFW\_BUILD\_MIPMAPS\_BIT flag is set, all mipmap levels for the loaded texture are generated and uploaded to texture memory.

Unless the flag GLFW\_ORIGIN\_UL\_BIT is set, the origin of the texture is the lower left corner of the loaded image. If the flag GLFW\_ORIGIN\_UL\_BIT is set, however, the first pixel is the upper left corner.

For single component images (i.e. gray scale), the texture is uploaded as an alpha mask if the flag GLFW\_ALPHA\_MAP\_BIT flag is set, otherwise it is uploaded as a luminance texture.

## Notes

**glfwLoadMemoryTexture2D** supports the Truevision Targa version 1 file format (.TGA). Supported pixel formats are: 8-bit gray scale, 8-bit paletted (24/32-bit color), 24-bit true color and 32-bit true color + alpha.

Paletted images are translated into true color or true color + alpha pixel formats.

The read texture is always rescaled to the nearest larger  $2^m \times 2^n$  resolution using bilinear interpolation, if necessary, since OpenGL<sup>®</sup> requires textures to have a  $2^m \times 2^n$  resolution.

If the GL\_SGIS\_generate\_mipmap extension, which is usually hardware accelerated, is supported by the OpenGL<sup>®</sup> implementation it will be used for mipmap generation. Otherwise the mipmaps will be generated by GLFW in software.

Since OpenGL<sup>®</sup> 1.0 does not support single component alpha maps, alpha map textures are converted to RGBA format under OpenGL<sup>®</sup> 1.0 when the GLFW\_ALPHA\_MAP\_BIT flag is set and the loaded texture is a single component texture. The red, green and blue components are set to 1.0.

### 3.6.6 glfwLoadTextureImage2D

#### C language syntax

```
int glfwLoadTextureImage2D( GLFWimage *img, int flags )
```

#### Parameters

##### *img*

Pointer to a GLFWimage struct holding the information about the image to be loaded.

##### *flags*

Flags for controlling the texture loading process. Valid flags are listed in table 3.7.

#### Return values

The function returns GL\_TRUE if the texture was loaded successfully. Otherwise GL\_FALSE is returned.

#### Description

This function uploads the image specified by the parameter *img* to OpenGL<sup>®</sup> texture memory (using the **glTexImage2D** function).

If the GLFW\_BUILD\_MIPMAPS\_BIT flag is set, all mipmap levels for the loaded texture are generated and uploaded to texture memory.

Unless the flag GLFW\_ORIGIN\_UL\_BIT is set, the origin of the texture is the lower left corner of the loaded image. If the flag GLFW\_ORIGIN\_UL\_BIT is set, however, the first pixel is the upper left corner.

For single component images (i.e. gray scale), the texture is uploaded as an alpha mask if the flag GLFW\_ALPHA\_MAP\_BIT flag is set, otherwise it is uploaded as a luminance texture.

#### Notes

**glfwLoadTextureImage2D** supports the Truevision Targa version 1 file format (.TGA). Supported pixel formats are: 8-bit gray scale, 8-bit paletted (24/32-bit color), 24-bit true color and 32-bit true color + alpha.

Paletted images are translated into true color or true color + alpha pixel formats.

The read texture is always rescaled to the nearest larger  $2^m \times 2^n$  resolution using bilinear interpolation, if necessary, since OpenGL<sup>®</sup> requires textures to have a  $2^m \times 2^n$  resolution.

If the GL\_SGIS\_generate\_mipmap extension, which is usually hardware accelerated, is supported by the OpenGL<sup>®</sup> implementation it will be used for mipmap generation. Otherwise the mipmaps will be generated by GLFW in software.

Since OpenGL<sup>®</sup> 1.0 does not support single component alpha maps, alpha map textures are converted to RGBA format under OpenGL<sup>®</sup> 1.0 when the `GLFW_ALPHA_MAP_BIT` flag is set and the loaded texture is a single component texture. The red, green and blue components are set to 1.0.

## 3.7 OpenGL Extension Support

One of the great features of OpenGL<sup>®</sup> is its support for extensions, which allow independent vendors to supply non-standard functionality in their OpenGL<sup>®</sup> implementations. As the mechanism for querying extensions varies among systems, GLFW provides an operating system independent interface for querying OpenGL<sup>®</sup> version, extensions and entry points.

### 3.7.1 glfwExtensionSupported

#### C language syntax

```
int glfwExtensionSupported( const char *extension )
```

#### Parameters

##### *extension*

A null terminated ISO 8859-1 string containing the name of an OpenGL<sup>®</sup> extension.

#### Return values

The function returns GL\_TRUE if the extension is supported. Otherwise it returns GL\_FALSE.

#### Description

This function does a string search in the list of supported OpenGL<sup>®</sup> extensions to find if the specified extension is listed.

#### Notes

An OpenGL<sup>®</sup> context must be created before this function can be called (i.e. an OpenGL<sup>®</sup> window must have been opened with **glfwOpenWindow**).

In addition to checking for OpenGL<sup>®</sup> extensions, GLFW also checks for extensions in the operating system “glue API”, such as WGL extensions under Microsoft Windows and GLX extensions under the X Window System.

### 3.7.2 glfwGetProcAddress

#### C language syntax

```
void * glfwGetProcAddress( const char *procname )
```

## Parameters

### *procname*

A null terminated ISO 8859-1 string containing the name of an OpenGL<sup>®</sup> extension function.

## Return values

The function returns the address of the specified OpenGL<sup>®</sup> function, if it is available. Otherwise NULL is returned.

## Description

This function acquires the pointer to an OpenGL<sup>®</sup> extension function. Some (but not all) OpenGL<sup>®</sup> extensions define new API functions, which are usually not available through normal linking. It is therefore necessary to get access to those API functions at runtime.

## Notes

An OpenGL<sup>®</sup> context must be created before this function can be called (i.e. an OpenGL<sup>®</sup> window must have been opened with **glfwOpenWindow**).

Some systems do not support dynamic function pointer retrieval, in which case **glfwGetProcAddress** will always return NULL.

## 3.7.3 glfwGetGLVersion

### C language syntax

```
void glfwGetGLVersion( int *major, int *minor, int *rev )
```

## Parameters

### *major*

Pointer to an integer that will hold the major version number.

### *minor*

Pointer to an integer that will hold the minor version number.

### *rev*

Pointer to an integer that will hold the revision.

## Return values

The function returns the major and minor version numbers and the revision for the currently used OpenGL<sup>®</sup> implementation.

**Description**

This function returns the OpenGL<sup>®</sup> implementation version. This is a convenient function that parses the version number information at the beginning of the string returned by calling `glGetString( GL_VERSION )`. The OpenGL<sup>®</sup> version information can be used to determine what functionality is supported by the used OpenGL<sup>®</sup> implementation.

**Notes**

An OpenGL<sup>®</sup> context must be created before this function can be called (i.e. an OpenGL<sup>®</sup> window must have been opened with **glfwOpenWindow**).

## 3.8 Threads

A thread is a separate execution path within a process. All threads within a process share the same address space and resources. Threads execute in parallel, either virtually by means of time-sharing on a single processor, or truly in parallel on multiple processors. Even on a multi-processor system, time-sharing is employed in order to maximize processor utilization and to ensure fair scheduling. GLFW provides an operating system independent interface to thread management.

### 3.8.1 glfwCreateThread

#### C language syntax

```
GLFWthread glfwCreateThread( GLFWthreadfun fun, void *arg )
```

#### Parameters

##### *fun*

A pointer to a function that acts as the entry point for the new thread. The function should have the following C language prototype:

```
void GLFWCALL functionname( void *arg );
```

Where *functionname* is the name of the thread function, and *arg* is the user supplied argument (see below).

##### *arg*

An arbitrary argument for the thread. *arg* will be passed as the argument to the thread function pointed to by *fun*. For instance, *arg* can point to data that is to be processed by the thread.

#### Return values

The function returns a thread identification number if the thread was created successfully. This number is always positive. If the function fails, a negative number is returned.

#### Description

This function creates a new thread, which executes within the same address space as the calling process. The thread entry point is specified with the *fun* argument.

Once the thread function *fun* returns, the thread dies.

#### Notes

Even if the function returns a positive thread ID, indicating that the thread was created successfully, the thread may be unable to execute, for instance if the thread start address is not a valid thread entry point.



### 3.8.2 glfwDestroyThread

#### C language syntax

```
void glfwDestroyThread( GLFWthread ID )
```

#### Parameters

##### *ID*

A thread identification handle, which is returned by **glfwCreateThread** or **glfwGetThreadID**.

#### Return values

none

#### Description

This function kills a running thread and removes it from the thread list.

#### Notes

This function is a very dangerous operation, which may interrupt a thread in the middle of an important operation, and its use is discouraged. You should always try to end a thread in a graceful way using thread communication, and use **glfwWaitThread** in order to wait for the thread to die.

### 3.8.3 glfwWaitThread

#### C language syntax

```
int glfwWaitThread( GLFWthread ID, int waitmode )
```

#### Parameters

##### *ID*

A thread identification handle, which is returned by **glfwCreateThread** or **glfwGetThreadID**.

##### *waitmode*

Can be either `GLFW_WAIT` or `GLFW_NOWAIT`.

#### Return values

The function returns `GL_TRUE` if the specified thread died after the function was called, or the thread did not exist, in which case **glfwWaitThread** will return immediately regardless of *waitmode*. The function returns `GL_FALSE` if *waitmode* is `GLFW_NOWAIT`, and the specified thread exists and is still running.

**Description**

If *waitmode* is `GLFW_WAIT`, the function waits for a thread to die. If *waitmode* is `GLFW_NOWAIT`, the function checks if a thread exists and returns immediately.

**3.8.4 glfwGetThreadID****C language syntax**

```
GLFWthread glfwGetThreadID( void )
```

**Parameters**

none

**Return values**

The function returns a thread identification handle for the calling thread.

**Description**

This function determines the thread ID for the calling thread. The ID is the same value as was returned by **glfwCreateThread** when the thread was created.

## 3.9 Mutexes

Mutexes are used to securely share data between threads. A mutex object can only be owned by one thread at a time. If more than one thread requires access to a mutex object, all but one thread will be put to sleep until they get access to it.

### 3.9.1 glfwCreateMutex

#### C language syntax

```
GLFWmutex glfwCreateMutex( void )
```

#### Parameters

none

#### Return values

The function returns a mutex handle, or NULL if the mutex could not be created.

#### Description

This function creates a mutex object, which can be used to control access to data that is shared between threads.

### 3.9.2 glfwDestroyMutex

#### C language syntax

```
void glfwDestroyMutex( GLFWmutex mutex )
```

#### Parameters

*mutex*

A mutex object handle.

#### Return values

none

#### Description

This function destroys a mutex object. After a mutex object has been destroyed, it may no longer be used by any thread.

### 3.9.3 glfwLockMutex

#### C language syntax

```
void glfwLockMutex( GLFWmutex mutex )
```

#### Parameters

***mutex***

A mutex object handle.

#### Return values

none

#### Description

This function will acquire a lock on the selected mutex object. If the mutex is already locked by another thread, the function will block the calling thread until it is released by the locking thread. Once the function returns, the calling thread has an exclusive lock on the mutex. To release the mutex, call **glfwUnlockMutex**.

### 3.9.4 glfwUnlockMutex

#### C language syntax

```
void glfwUnlockMutex( GLFWmutex mutex )
```

#### Parameters

***mutex***

A mutex object handle.

#### Return values

none

#### Description

This function releases the lock of a locked mutex object.

## 3.10 Condition Variables

Condition variables are used to synchronize threads. A thread can wait for a condition variable to be signaled by another thread.

### 3.10.1 glfwCreateCond

#### C language syntax

```
GLFWcond glfwCreateCond( void )
```

#### Parameters

none

#### Return values

The function returns a condition variable handle, or NULL if the condition variable could not be created.

#### Description

This function creates a condition variable object, which can be used to synchronize threads.

### 3.10.2 glfwDestroyCond

#### C language syntax

```
void glfwDestroyCond( GLFWcond cond )
```

#### Parameters

*cond*

A condition variable object handle.

#### Return values

none

#### Description

This function destroys a condition variable object. After a condition variable object has been destroyed, it may no longer be used by any thread.

### 3.10.3 glfwWaitCond

#### C language syntax

```
void glfwWaitCond( GLFWcond cond, GLFWmutex mutex, double timeout )
```

#### Parameters

***cond***

A condition variable object handle.

***mutex***

A mutex object handle.

***timeout***

Maximum time to wait for the condition variable. The parameter can either be a positive time (in seconds), or GLFW\_INFINITY.

#### Return values

none

#### Description

This function atomically unlocks the mutex specified by *mutex*, and waits for the condition variable *cond* to be signaled. The thread execution is suspended and does not consume any CPU time until the condition variable is signaled or the amount of time specified by *timeout* has passed. If *timeout* is GLFW\_INFINITY, **glfwWaitCond** will wait forever for *cond* to be signaled. Before returning to the calling thread, **glfwWaitCond** automatically re-acquires the mutex.

#### Notes

The mutex specified by *mutex* must be locked by the calling thread before entrance to **glfwWaitCond**.

A condition variable must always be associated with a mutex, to avoid the race condition where a thread prepares to wait on a condition variable and another thread signals the condition just before the first thread actually waits on it.

### 3.10.4 glfwSignalCond

#### C language syntax

```
void glfwSignalCond( GLFWcond cond )
```

**Parameters*****cond***

A condition variable object handle.

**Return values**

none

**Description**

This function restarts one of the threads that are waiting on the condition variable *cond*. If no threads are waiting on *cond*, nothing happens. If several threads are waiting on *cond*, exactly one is restarted, but it is not specified which.

**Notes**

When several threads are waiting for the condition variable, which thread is started depends on operating system scheduling rules, and may vary from system to system and from time to time.

### 3.10.5 glfwBroadcastCond

**C language syntax**

```
void glfwBroadcastCond( GLFWcond cond )
```

**Parameters*****cond***

A condition variable object handle.

**Return values**

none

**Description**

This function restarts all the threads that are waiting on the condition variable *cond*. If no threads are waiting on *cond*, nothing happens.

**Notes**

When several threads are waiting for the condition variable, the order in which threads are started depends on operating system scheduling rules, and may vary from system to system and from time to time.

## 3.11 Miscellaneous

### 3.11.1 glfwEnable/glfwDisable

#### C language syntax

```
void glfwEnable( int token )
void glfwDisable( int token )
```

#### Parameters

##### *token*

A value specifying a feature to enable or disable. Valid tokens are listed in table 3.8.

#### Return values

none

#### Description

**glfwEnable** is used to enable a certain feature, while **glfwDisable** is used to disable it. Below follows a description of each feature.

#### GLFW\_AUTO\_POLL\_EVENTS

When GLFW\_AUTO\_POLL\_EVENTS is enabled, **glfwPollEvents** is automatically called each time that **glfwSwapBuffers** is called, immediately after the buffer swap itself.

When GLFW\_AUTO\_POLL\_EVENTS is disabled, calling **glfwSwapBuffers** will not result in a call to **glfwPollEvents**. This can be useful if for example **glfwSwapBuffers** needs to be called from within a callback function, since calling **glfwPollEvents** from a callback function is not allowed.

#### GLFW\_KEY\_REPEAT

When GLFW\_KEY\_REPEAT is enabled, the key and character callback functions are called repeatedly when a key is held down long enough (according to the system key repeat configuration).

When GLFW\_KEY\_REPEAT is disabled, the key and character callback functions are only called once when a key is pressed (and once when it is released).

#### GLFW\_MOUSE\_CURSOR

When GLFW\_MOUSE\_CURSOR is enabled, the mouse cursor is visible, and mouse coordinates are relative to the upper left corner of the client area of the GLFW window. The coordinates are limited to the client area of the window.

When GLFW\_MOUSE\_CURSOR is disabled, the mouse cursor is invisible, and mouse coordinates are not limited to the drawing area of the window. It is as if the mouse coordinates are received directly from the mouse, without being restricted or manipulated by the windowing system.



### GLFW\_STICKY\_KEYS

When `GLFW_STICKY_KEYS` is enabled, keys which are pressed will not be released until they are physically released and checked with **`glfwGetKey`**. This behavior makes it possible to catch keys that were pressed and then released again between two calls to **`glfwPollEvents`**, **`glfwWaitEvents`** or **`glfwSwapBuffers`**, which would otherwise have been reported as released. Care should be taken when using this mode, since keys that are not checked with **`glfwGetKey`** will never be released. Note also that enabling `GLFW_STICKY_KEYS` does not affect the behavior of the keyboard callback functionality.

When `GLFW_STICKY_KEYS` is disabled, the status of a key that is reported by **`glfwGetKey`** is always the physical state of the key. Disabling `GLFW_STICKY_KEYS` also clears the sticky information for all keys.

### GLFW\_STICKY\_MOUSE\_BUTTONS

When `GLFW_STICKY_MOUSE_BUTTONS` is enabled, mouse buttons that are pressed will not be released until they are physically released and checked with **`glfwGetMouseButton`**. This behavior makes it possible to catch mouse buttons which were pressed and then released again between two calls to **`glfwPollEvents`**, **`glfwWaitEvents`** or **`glfwSwapBuffers`** (with `GLFW_AUTO_POLL_EVENTS` enabled), which would otherwise have been reported as released. Care should be taken when using this mode, since mouse buttons that are not checked with **`glfwGetMouseButton`** will never be released. Note also that enabling `GLFW_STICKY_MOUSE_BUTTONS` does not affect the behavior of the mouse button callback functionality.

When `GLFW_STICKY_MOUSE_BUTTONS` is disabled, the status of a mouse button that is reported by **`glfwGetMouseButton`** is always the physical state of the mouse button. Disabling `GLFW_STICKY_MOUSE_BUTTONS` also clears the sticky information for all mouse buttons.

### GLFW\_SYSTEM\_KEYS

When `GLFW_SYSTEM_KEYS` is enabled, pressing standard system key combinations, such as `Alt+Tab` under Windows, will give the normal behavior. Note that when `Alt+Tab` is issued under Windows in this mode so that the GLFW application is deselected when GLFW is operating in fullscreen mode, the GLFW application window will be minimized and the video mode will be set to the original desktop mode. When the GLFW application is re-selected, the video mode will be set to the GLFW video mode again.

When `GLFW_SYSTEM_KEYS` is disabled, pressing standard system key combinations will have no effect, since those key combinations are blocked by GLFW. This mode can be useful in situations when the GLFW program must not be interrupted (normally for games in fullscreen mode).

## 3.11.2 glfwGetNumberOfProcessors

### C language syntax

```
int glfwGetNumberOfProcessors( void )
```

**Parameters**

none

**Return values**

The function returns the number of active processors in the system.

**Description**

This function determines the number of active processors in the system.

**Notes**

Systems with several logical processors per physical processor, also known as SMT (Symmetric Multi-Threading) processors, will report the number of logical processors.

Name	Controls	Default
GLFW_AUTO_POLL_EVENTS	Automatic event polling when <b>glfwSwapBuffers</b> is called	Enabled
GLFW_KEY_REPEAT	Keyboard key repeat	Disabled
GLFW_MOUSE_CURSOR	Mouse cursor visibility	Enabled in windowed mode. Disabled in fullscreen mode.
GLFW_STICKY_KEYS	Keyboard key “stickiness”	Disabled
GLFW_STICKY_MOUSE_BUTTONS	Mouse button “stickiness”	Disabled
GLFW_SYSTEM_KEYS	Special system key actions	Enabled

Table 3.8: Tokens for **glfwEnable**/**glfwDisable**

## Appendix A

# GLFW Compatibility

This chapter describes the various API extensions used by this version of GLFW. It lists what are essentially implementation details, but which are nonetheless vital knowledge for developers wishing to deploy their applications on machines with varied specifications.

Note that the information in this appendix is not a part of the API specification but merely list some of the preconditions for certain parts of the API to function on a given machine. As such, any part of it may change in future versions without this being considered a breaking API change.

### A.1 ICCCM and EWMH Conformance

As GLFW uses **Xlib**, directly, without any intervening toolkit library, it has sole responsibility for interacting well with the many and varied window managers in use on Unix-like systems. In order for applications and window managers to work well together, a number of standards and conventions have been developed that regulate behavior outside the scope of the X11 API; most importantly the **Inter-Client Communication Conventions Manual** (ICCCM) and **Extended Window Manager Hints** (EWMH) standards.

GLFW uses the ICCCM **WM\_DELETE\_WINDOW** protocol to intercept the user attempting to close the GLFW window. If the running window manager does not support this protocol, the close callback will never be called.

GLFW uses the EWMH **\_NET\_WM\_PING** protocol, allowing the window manager notify the user when the application has stopped responding, i.e. when it has ceased to process events. If the running window manager does not support this protocol, the user will not be notified if the application locks up.

GLFW uses the EWMH **\_NET\_WM\_STATE** protocol to tell the window manager to make the GLFW window fullscreen. If the running window manager does not support this protocol, fullscreen windows may not work properly. GLFW has a fallback code path in case this protocol is unavailable, but every window manager behaves slightly differently in this regard.

## A.2 GLX Extensions

The **GLX** API is used to create OpenGL<sup>®</sup> contexts on Unix-like systems using the X Window System.

GLFW uses the **GLXFBConfig** API to enumerate and select framebuffer pixel formats. This requires either **GLX** 1.3 or greater, or the **GLX\_SGIX\_fbconfig** extension. Where both are available, the SGIX extension is preferred. If neither is available, GLFW will be unable to open windows.

GLFW uses the **GLX\_SGI\_swap\_control** extension to provide vertical retrace synchronization (or “vsync”). Where this extension is unavailable, calling **glfwSwapInterval** will have no effect.

GLFW uses the **GLX\_ARB\_multisample** extension to create contexts with multisampling anti-aliasing. Where this extension is unavailable, the **GLFW\_FSAA\_SAMPLES** hint will have no effect.

GLFW uses the **GLX\_ARB\_create\_context** extension when available, even when creating OpenGL<sup>®</sup> contexts of version 2.1 and below. Where this extension is unavailable, the **GLFW\_OPENGL\_VERSION\_MAJOR** and **GLFW\_OPENGL\_VERSION\_MINOR** hints will only be partially supported, the **GLFW\_OPENGL\_DEBUG\_CONTEXT** hint will have no effect, and setting the **GLFW\_OPENGL\_PROFILE** or **GLFW\_FORWARD\_COMPAT** hints to a non-zero value will cause **glfwOpenWindow** to fail.

GLFW uses the **GLX\_ARB\_create\_context\_profile** extension to provide support for context profiles. Where this extension is unavailable, setting the **GLFW\_OPENGL\_PROFILE** hint to anything but zero will cause **glfwOpenWindow** to fail.

## A.3 WGL Extensions

The **WGL** API is used to create OpenGL<sup>®</sup> contexts on Microsoft Windows and other implementations of the Win32 API, such as Wine.

GLFW uses either the **WGL\_EXT\_extension\_string** or the **WGL\_ARB\_extension\_string** extension to check for the presence of all other **WGL** extensions listed below. If both are available, the EXT one is preferred. If neither is available, no other extensions are used and many GLFW features related to context creation will have no effect or cause errors when used.

GLFW uses the **WGL\_EXT\_swap\_control** extension to provide vertical retrace synchronization (or “vsync”). Where this extension is unavailable, calling **glfwSwapInterval** will have no effect.

GLFW uses the **WGL\_ARB\_pixel\_format** and **WGL\_ARB\_multisample** extensions to create contexts with multisampling anti-aliasing. Where these extensions are unavailable, the **GLFW\_FSAA\_SAMPLES** hint will have no effect.

GLFW uses the **WGL\_ARB\_create\_context** extension when available, even when creating OpenGL<sup>®</sup> contexts of version 2.1 and below. Where this extension is unavailable, the **GLFW\_OPENGL\_VERSION\_MAJOR** and **GLFW\_OPENGL\_VERSION\_MINOR** hints will only be

partially supported, the `GLFW_OPENGL_DEBUG_CONTEXT` hint will have no effect, and setting the `GLFW_OPENGL_PROFILE` or `GLFW_FORWARD_COMPAT` hints to a non-zero value will cause **glfwOpenWindow** to fail.

GLFW uses the **WGL\_ARB\_create\_context\_profile** extension to provide support for context profiles. Where this extension is unavailable, setting the `GLFW_OPENGL_PROFILE` hint to anything but zero will cause **glfwOpenWindow** to fail.

## A.4 OpenGL 3.0+ on Mac OS X

Support for OpenGL 3.0 and above was introduced with Mac OS X 10.7, and even then only forward-compatible OpenGL 3.2 core profile contexts are supported. There is also still no mechanism for requesting debug contexts. Versions of Mac OS X earlier than 10.7 support at most OpenGL version 2.1.

Because of this, on Mac OS X 10.7, the `GLFW_OPENGL_VERSION_MAJOR` and `GLFW_OPENGL_VERSION_MINOR` hints will fail if given a version above 3.2, the `GLFW_FORWARD_COMPAT` is required for creating OpenGL 3.2 contexts, the `GLFW_OPENGL_DEBUG_CONTEXT` hint is ignored and setting the `GLFW_OPENGL_PROFILE` hint to anything except zero or `GLFW_OPENGL_CORE_PROFILE` will cause **glfwOpenWindow** to fail.

Also, on Mac OS X 10.6 and below, the `GLFW_OPENGL_VERSION_MAJOR` and `GLFW_OPENGL_VERSION_MINOR` hints will fail if given a version above 2.1, the `GLFW_OPENGL_DEBUG_CONTEXT` hint will have no effect, and setting the `GLFW_OPENGL_PROFILE` or `GLFW_FORWARD_COMPAT` hints to a non-zero value will cause **glfwOpenWindow** to fail.