Preface

OpenGL™ (GL for Graphics Library™) is a software interface to graphics hardware. This interface consists of several hundred functions that allow you, a graphics programmer, to specify the objects and operations needed to produce high-quality color images of three-dimensional objects. Many of these functions are actually simple variations of each other, so in reality there are only 120 substantially different functions.

As complements to the core set of OpenGL functions, the OpenGL Utility Library (GLU) and the OpenGL Extension to the X Window System™ (GLX) provide useful supporting features. This manual explains what all these functions do; it has the following chapters:

- **Chapter 1, "Introduction to OpenGL,"** provides a brief statement of the major underlying concepts embodied in OpenGL. It uses a high-level block diagram to discuss in conceptual terms all the major stages of processing performed by OpenGL.
- **Chapter 2, "Overview of Commands and Routines,"** describes in more detail how input data (in the form of vertices specifying a geometric object or pixels defining an image) is processed and how you can control this processing using the functions that comprise OpenGL. Functions belonging to GLU and GLX are also discussed.
- **Chapter 3, "Summary of Commands and Routines,"** lists the OpenGL commands in groups according to what sort of tasks they perform. Full prototypes are given so that you can use this section as a quick reference once you understand what the commands accomplish.
- **Chapter 4, "Defined Constants and Associated Commands,"** lists the constants defined in OpenGL and the commands that use them.

- **Chapter 5, "OpenGL Reference Pages,"** which forms the bulk of this manual, contains descriptions of each set of related OpenGL commands. (Commands with parameters that differ only in data type are described together, for example.) Each reference page fully describes the relevant parameters, the effect of the commands, and what errors might be generated by using the commands.
- **Chapter 6, "GLU Reference Pages,"** contains the reference pages for all the GLU routines.
- **Chapter 7, "GLX Reference Pages,"** contains the reference pages for the GLX routines.

What You Should Know Before Reading This Manual

This manual is designed to be used as the companion reference volume to the OpenGL Programming Guide by Jack Neider, Tom Davis, and Mason Woo (Reading, MA: Addison–Wesley Publishing Company). The focus of this Reference Manual is how OpenGL works, while the Programming Guide's focus is how to use OpenGL. For a complete understanding of OpenGL, you need both types of information. Another difference between these two books is that most of the content of this Reference Manual is organized alphabetically, based on the assumption that you know what you don't know and therefore need only to look up a description of a particular command; the Programming Guide is organized like a tutorial—it explains the simpler OpenGL concepts first and builds up to the more complex ones. Although the command descriptions in this manual don't necessarily require you to have read the Programming Guide, your understanding of the intended usage of the commands will be much more complete if you have read it. Both books also assume that you know how to program in C.


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Chapter 1
Introduction to OpenGL

As a software interface for graphics hardware, OpenGL's main purpose is to render two- and three-dimensional objects into a frame buffer. These objects are described as sequences of vertices (which define geometric objects) or pixels (which define images). OpenGL performs several processing steps on this data to convert it to pixels to form the final desired image in the frame buffer.

This chapter presents a global view of how OpenGL works; it contains the following major sections:

- "OpenGL Fundamentals" briefly explains basic OpenGL concepts, such as what a graphic primitive is and how OpenGL implements a client–server execution model.
- "Basic OpenGL Operation" gives a high-level description of how OpenGL processes data and produces a corresponding image in the frame buffer.

OpenGL Fundamentals
This section explains some of the concepts inherent in OpenGL.

Primitives and Commands
OpenGL draws primitives—points, line segments, or polygons—subject to several selectable modes. You can control modes independently of each other; that is, setting one mode doesn't affect whether other modes are set (although many modes may interact to determine what eventually ends up in the frame buffer). Primitives are specified, modes are set, and other OpenGL operations are described by issuing commands in the form of function calls.

Primitives are defined by a group of one or more vertices. A vertex defines a point, an endpoint of a line, or a corner of a polygon where two edges meet. Data (consisting of vertex coordinates, colors, norms, texture coordinates, and edge flags) is associated with a vertex, and each vertex and its associated data are processed independently, in order, and in the same way. The only exception to this rule is if the group of vertices must be clipped so that a particular primitive fits within a specified region; in this case, vertex data may be modified and new vertices created. The type of clipping depends on which primitive the group of vertices represents.

Commands are always processed in the order in which they are received, although there may be an indeterminate delay before a command takes effect. This means that each primitive is drawn completely before any subsequent command takes effect. It also means that state-querying commands return data that's consistent with complete execution of all previously issued OpenGL commands.

Procedural versus Descriptive
OpenGL provides you with fairly direct control over the fundamental operations of two- and three-dimensional graphics. This includes specification of such parameters as transformation matrices, lighting equation coefficients, anti-aliasing methods, and pixel update operations. However, it doesn't provide you with a means for describing or modeling complex geometric objects. Thus, the OpenGL commands you issue specify how a certain result should be produced (what procedure should be followed) rather than what exactly that result should look like. That is, OpenGL is fundamentally procedural rather than descriptive. Because of this procedural nature, it helps to know how OpenGL works—the order in which it carries out its operations, for example—in order to fully understand how to use it.

Execution Model
The model for interpretation of OpenGL commands is client–server. An application (the client) issues commands, which are interpreted and processed by OpenGL (the server). The server may or may not operate on the same computer as the client. In this sense, OpenGL is network-transparent. A server can maintain several GL contexts, each of which is an encapsulated GL state. A client can connect to any one of these contexts. The required network protocol can be implemented by augmenting an already existing protocol (such as that of the X Window System) or by using an independent protocol.

No OpenGL commands are provided for obtaining user input. The effects of OpenGL commands on the frame buffer are ultimately controlled by the window system that allocates frame buffer resources. The window system determines which portions of the frame buffer OpenGL may access at any given time and communicates to OpenGL how those portions are structured. Therefore, there are no OpenGL commands to configure the frame buffer or initialize OpenGL. Frame buffer configuration is done outside of OpenGL in conjunction with the window system; OpenGL initialization takes place when the window system allocates a window for OpenGL rendering. (GLX, the X extension of the OpenGL interface, provides these capabilities, as described in "OpenGL Extension to the X Window System.")

Basic OpenGL Operation
The figure shown below gives an abstract, high-level block diagram of how OpenGL processes data. In the diagram, commands enter from the left and proceed through what can be thought of as a processing pipeline. Some commands specify geometric objects to be drawn, and others control how the objects are handled during the various processing stages.

Figure 1-1 OpenGL Block Diagram
As shown by the first block in the diagram, rather than having all commands proceed immediately through the pipeline, you can choose to accumulate some of them in a display list for processing at a later time.

The evaluator stage of processing provides an efficient means for approximating curve and surface geometry by evaluating polynomial commands of input values. During the next stage, per-vertex operations and primitive assembly, OpenGL processes geometric primitives—points, line segments, and polygons, all of which are described by vertices. Vertices are transformed and lit, and primitives are clipped to the viewport in preparation for the next stage.

Rasterization produces a series of frame buffer addresses and associated values using a two-dimensional description of a point, line segment, or polygon. Each fragment so produced is fed into the last stage, per-fragment operations, which performs the final operations on the data before it's stored as pixels in the frame buffer. These operations include conditional updates to the frame buffer based on incoming and previously stored z-values (for z-buffering) and blending of incoming pixel colors with stored colors, as well as masking and other logical operations on pixel values.

Input data can be in the form of pixels rather than vertices. Such data, which might describe an image for use in texture mapping, skips the first stage of processing described above and instead is processed as pixels, in the pixel operations stage. The result of this stage is either stored as texture memory, for use in the rasterization stage, or rasterized and the resulting fragments merged into the frame buffer just as if they were generated from geometric data.

All elements of OpenGL state, including the contents of the texture memory and even of the frame buffer, can be obtained by an OpenGL application.

Chapter 2
Overview of Commands and Routines
Many OpenGL commands pertain specifically to drawing objects such as points, lines, polygons, and bitmaps. Other commands control the way that some of this drawing occurs (such as those that enable anti-aliasing or texturing). Still other commands are specifically concerned with frame buffer
manipulation. This chapter briefly describes how all the OpenGL commands work together to create
the OpenGL processing pipeline. Brief overviews are also given of the routines comprising the OpenGL
Utility Library (GLU) and the OpenGL extensions to the X Window System (GLX).

This chapter has the following main sections:
- "OpenGL Processing Pipeline" expands the discussion in Chapter 1 by explaining how
  specific OpenGL commands control the processing of data.
- "Additional OpenGL Commands" discusses several sets of OpenGL commands not covered in
  the previous section.
- "OpenGL Utility Library" describes the GLU routines that are available.
- "OpenGL Extension to the X Window System" describes the GLX routines.

**OpenGL Processing Pipeline**

Now that you have a general idea of how OpenGL works from Chapter 1, let's take a closer look at the
stages in which data is actually processed and tie these stages to OpenGL commands. The figure shown
on the next page is a more detailed block diagram of the OpenGL processing pipeline.

For most of the pipeline, you can see three vertical arrows between the major stages. These arrows
represent vertices and the two primary types of data that can be associated with vertices: color values and
texture coordinates. Also note that vertices are assembled into primitives, then to fragments, and
finally to pixels in the frame buffer. This progression is discussed in more detail in the following
sections.

As you continue reading, be aware that we've taken some liberties with command names. Many
OpenGL commands are simple variations of each other, differing mostly in the data type of arguments;
some commands differ in the number of related arguments and whether those arguments can be
specified as a vector or whether they must be specified separately in a list. For example, if you use the
`glVertex2f()` command, you need to supply x and y coordinates as 32-bit floating-point numbers; with
`glVertex3sv()`, you must supply an array of three short (16-bit) integer values for x, y, and z. For
simplicity, only the base name of the command is used in the discussion that follows, and an asterisk
is included to indicate that there may be more to the actual command name than is being shown. For
example, `glVertex*()` stands for all variations of the command you use to specify vertices.

Also keep in mind that the effect of an OpenGL command may vary depending on whether certain
modes are enabled. For example, you need to enable lighting if the lighting-related commands are to
have the desired effect of producing a properly lit object. To enable a particular mode, you use the
`glEnable()` command and supply the appropriate constant to identify the mode (for example,
`GL_LIGHTING`). Related commands you might use to control how lighting calculations are performed include
`glLightModel*()`, `glColorMaterial()`, and `glColor*()`.

In addition to specifying colors and normal vectors, you may define the desired lighting conditions with
the `glLight*()` and `glLightModel*()` commands. The lighting-related commands take the current
lighting environment into account, as well as the lighting properties of the objects being rendered.

When you have all the lighting information set up, you can specify the desired colors and normals
with the `glColor*()` and `glNormal*()` commands. These commands can be used multiple times,
and the last value specified for a given vertex will be used.

To specify texture coordinates, you can use the `glTexCoord*()` command. These coordinates
are transformed by the texture matrix, which is controlled with the `glMatrixMode()` and
`glLoadIdentity()` commands.

**Primitives**

During the next stage of processing, primitives are converted to pixel fragments in several steps:
primitives are clipped appropriately, whatever corresponding adjustments are necessary are made to
the color and texture data, and the relevant coordinates are transformed to window coordinates.
Finally, rasterization converts the clipped primitives to pixel fragments.

**Clipping**

Points, line segments, and polygons are handled slightly differently during clipping. Points are either
retained in their original state (if they're inside the clip volume) or discarded (if they're outside). If
portions of line segments or polygons are outside the clip volume, new vertices are generated at the clip
dots. For polygons, an entire edge may need to be constructed between such new vertices. For both

line segments and polygons that are clipped, the edge flag, color, and texture information is assigned to all new vertices.

Clipping actually happens in two steps:
1. **Application-specific clipping**—Immediately after primitives are assembled, they’re clipped in eye coordinates as necessary for any arbitrary clipping planes you’ve defined for your application with glClipPlane(). (OpenGL requires support for at least six such application-specific clipping planes.)
2. **View volume clipping**—Next, primitives are transformed by the projection matrix into clip coordinates and clipped by the corresponding viewing volume. This matrix can be controlled by the previously mentioned matrix transformation commands but is most typically specified by glFrustum() or glOrtho().

### Transforming to Window Coordinates
Before clip coordinates can be converted to window coordinates, they are normalized by dividing by the value of w to yield normalized device coordinates. After that, the viewport transformation applied to these normalized coordinates produces window coordinates. You control the viewport, which determines the area of the on-screen window that displays an image, with glViewport().

### Rasterization
Rasterization is the process by which a primitive is converted to a two-dimensional image. Each point of this image contains such information as color, depth, and texture data. Together, a point and its associated information are called a fragment. The current raster position (as specified with glRasterPos()) is used in various ways during this stage for pixel drawing and bitmaps. As discussed below, different issues arise when rasterizing the three different types of primitives; in addition, pixel rectangles and bitmaps need to be rasterized.

### Primitives
You control how primitives are rasterized with commands that allow you to choose dimensions and stipple patterns: glPointSize(), glLineWidth(), glLineStipple(), and glPolygonStipple(). Additionally, you can control how the front and back faces of polygons are rasterized with glFrustrum() and glFrontFace() and glPolygonMode().

### Pixels
Several commands control pixel storage and transfer modes. The command glPixelStore() controls the encoding of pixels in client memory, and glPixelTransfer() controls how pixels are processed before being placed in the frame buffer. A pixel rectangle is specified with glDrawPixels(); its rasterization is controlled with glPixelZoom().

### Bitmaps
Bitmaps are rectangles of zeros and ones specifying a particular pattern of fragments to be produced. Each of these fragments has the same associated data. A bitmap is specified using glBitmap().

### Texture Memory
Texture mapping maps a portion of a specified texture image onto each primitive when texturing is enabled. This mapping is accomplished by using the color of the texture image at the location indicated by a fragment’s texture coordinates to modify the fragment’s RGBA color. A texture image is specified using glTexImage2D() or glTexImage1D(). The commands glTexParameter() and glTexParameter() control how texture values are interpreted and applied to a fragment.

### Fog
You can have OpenGL blend a fog color with a rasterized fragment’s post-texturing color using a blending factor that depends on the distance between the viewpoint and the fragment. Use glFog() to specify the fog color and blending factor.

### Fragments
OpenGL allows a fragment produced by rasterization to modify the corresponding pixel in the frame buffer only if it passes a series of tests. If it does pass, the fragment’s data can be used directly to replace the existing frame buffer values, or it can be combined with existing data in the frame buffer, depending on the state of certain modes.

### Pixel Ownership Test
The first test is to determine whether the pixel in the frame buffer corresponding to a particular fragment is owned by the current OpenGL context. If so, the fragment proceeds to the next test. If not, the window system determines whether the fragment is discarded or whether any further fragment operations will be performed with that fragment. This test allows the window system to control OpenGL’s behavior when, for example, an OpenGL window is obscured.

### Scissor Test
With the glScissor() command, you can specify an arbitrary screen-aligned rectangle outside of which fragments will be discarded.

### Alpha Test
The alpha test (which is performed only in RGBA mode) discards a fragment depending on the outcome of a comparison between the fragment’s alpha value and a constant reference value. The comparison command and reference value are specified with glAlphaFunc().

### Stencil Test
The stencil test conditionally discards a fragment based on the outcome of a comparison between the fragment’s alpha value and a constant reference value. The comparison command and reference value are specified with glStencilFunc().

### Depth Buffer Test
The depth buffer test discards a fragment if a depth comparison fails; glDepthFunc() specifies the comparison command. The result of the depth comparison also affects the stencil buffer update value if stenciling is enabled.

### Blending
Blending combines a fragment’s R, G, B, and A values with those stored in the frame buffer at the corresponding location. The blending, which is performed only in RGBA mode, depends on the alpha value of the fragment and that of the corresponding currently stored pixel; it might also depend on the RGB values. You control blending with glBlendFunc(), which allows you to indicate the source and destination blending factors.

### Dithering
If dithering is enabled, a dithering algorithm is applied to the fragment’s color or color index value. This algorithm depends only on the fragment’s value and its x and y window coordinates.

### Logical Operations
Finally, a logical operation can be applied between the fragment and the value stored at the corresponding location in the frame buffer; the result replaces the current frame buffer value. You choose the desired logical operation with glLogicOp(). Logical operations are performed only on color indices, never on RGBA values.

### Pixels
During the previous stage of the OpenGL pipeline, fragments are converted to pixels in the frame buffer. The frame buffer is actually organized into a set of logical buffers—the color, depth, stencil, and accumulation buffers. The color buffer itself consists of a front left, front right, back left, back right, and some number of auxiliary buffers. You can issue commands to control these buffers, and you can directly read or copy pixels from them. (Note that the particular OpenGL context you’re using may not provide all of these buffers.)

**Frame Buffer Operations**

You can select into which buffer color values are written with `glDrawBuffer()`. In addition, four different commands are used to mask the writing of bits to each of the logical frame buffers after all per-fragment operations have been performed: `glIndexMask()`, `glColorMask()`, `glDepthMask()`, and `glStencilMask()`. The operation of the accumulation buffer is controlled with `glAccum()`. Finally, `glClear()` sets every pixel in a specified subset of the buffers to the value specified with `glClearColor()`, `glClearIndex()`, `glClearDepth()`, `glClearStencil()`, or `glClearAccum()`. 

**Reading or Copying Pixels**

You can read pixels from the frame buffer into memory, encode them in various ways, and store the encoded result in memory with `glReadPixels()`. In addition, you can copy a rectangle of pixel values from one region of the frame buffer to another with `glCopyPixels()`. The command `glReadBuffer()` controls from which color buffer the pixels are read or copied.

**Additional OpenGL Commands**

This section briefly describes special groups of commands that weren't explicitly shown as part of OpenGL's processing pipeline. These commands accomplish such diverse tasks as evaluating polynomials, using display lists, and obtaining the values of OpenGL state variables.

**Using Evaluators**

OpenGL’s evaluator commands allow you to use a polynomial mapping to produce vertices, normals, texture coordinates, and colors. These calculated values are then passed on to the pipeline as if they had been directly specified. The evaluator facility is also the basis for the NURBS (Non–Uniform Rational B–Spline) commands, which allow you to define curves and surfaces, as described later in this chapter under ‘OpenGL Utility Library.’

The first step involved in using evaluators is to define the appropriate one- or two-dimensional polynomial mapping using `glMap*()`. The domain values for this map can then be specified and evaluated in one of two ways:

- By defining a series of evenly spaced domain values to be mapped using `glMapGrid*()` and then evaluating a rectangular subset of that grid with `glEvalMesh*()`. A single point of the grid can be evaluated using `glEvalPoint*()`.
- By explicitly specifying a desired domain value as an argument to `glEvalCoord*()`, which evaluates the maps at that value.

**Performing Selection and Feedback**

Selection, feedback, and rendering are mutually exclusive modes of operation. Rendering is the normal, default mode during which fragments are produced by rasterization; in selection and feedback modes, no fragments are produced and therefore no frame buffer modification occurs. In selection mode, you can determine which primitives would be drawn into some region of a window; in feedback mode, information about primitives that would be rasterized is fed back to the application. You select among these three modes with `glRenderMode()`.

**Selection**

Selection works by returning the current contents of the name stack, which is an array of integer–valued names. You assign the names and build the name stack within the modeling code that specifies the geometry ... intersects the clip volume, a selection hit occurs. The hit record, which is written into the selection array you've supplied with `glSelectBuffer()`, contains information about the contents of the name stack at the time of the hit. (Note that `glSelectBuffer()` needs to be called before OpenGL is put into selection mode.)

You manipulate the name stack with `glPushName()`, `glLoadName()`, and `glPopName()`, and an OpenGL Utility Library routine for selection, `gluPickMatrix()`, which is described later in this chapter under ‘OpenGL Utility Library.”

**Feedback**

In feedback mode, each primitive that would be rasterized generates a block of values that is copied into the feedback array. You supply this array with `glFeedbackBuffer()`, which must be called before OpenGL is put into feedback mode. Each block of values begins with a code indicating the primitive type, followed by values that describe the primitive’s vertices and associated data. Entries are also written for bitmaps and pixel rectangles. Values are not guaranteed to be written into the feedback array until `glRenderMode()` is called to take OpenGL out of feedback mode. You can use `glPassThrough()` to supply a marker that’s returned in feedback mode as if it were a primitive.

**Using Display Lists**

A display list is simply a group of OpenGL commands that has been stored for subsequent execution. The `glNewList()` command begins the creation of a display list, and `glEndList()` ends it. With few exceptions, OpenGL commands called between `glNewList()` and `glEndList()` are appended to the display list, and optionally executed as well. (The reference page for `glNewList()` lists the commands that can’t be stored and executed from within a display list.) To trigger the execution of a list or set of lists, use `glCallList()` or `glCallLists()`, which supply the identifying number of a particular list or lists. You can manage the indices used to identify display lists with `glGenLists()`, `glListBase()`, and `glDeleteLists()`. Finally, you can delete a set of display lists with `glDeleteLists()`.

**Managing Modes and Execution**

The effect of many OpenGL commands depends on whether a particular mode is in effect. You use `glEnable()` and `glDisable()` to set such modes and `glIsEnabled()` to determine whether a particular mode is set.

You can control the execution of previously issued OpenGL commands with `glFinish()`, which forces all such commands to complete, or `glFlush()`, which ensures that all such commands will be completed in a finite time.

A particular implementation of OpenGL may allow certain behaviors to be controlled with hints, by using the `glHint()` command. Possible behaviors are the quality of color and texture coordinate interpolation, the accuracy of fog calculations, and the sampling quality of antialiased lines, points, or polygons.

**Obtaining State Information**

OpenGL maintains numerous state variables that affect the behavior of many commands. Some of these variables have specialized query commands: `glGetLight()`.
The OpenGL Utility Library (GLU) contains several groups of commands that complement the core OpenGL interface by providing support for auxiliary features. Since these utility routines make use of core OpenGL commands, any OpenGL implementation is guaranteed to support the utility routines. Note that the prefix for Utility Library routines is gl rather than gl.

Manipulating Images for Use in Texturing
GLU provides image scaling and automatic mipmapping routines to simplify the specification of texture images. The routine glScaleImage() scales a specified image to an accepted texture size; the resulting image can then be passed to OpenGL as a texture. The automatic mipmapping routines gluBuild1DMipmaps() and gluBuild2DMipmaps() create mipmapped texture images from a specified image and pass them to glTexImage1D() and glTexImage2D(), respectively.

Transforming Coordinates
Several commonly used matrix transformation routines are provided. You can set up a two-dimensional orthographic viewing region with gluOrtho2D(), a perspective viewing volume using gluPerspective(), or a viewing volume that's centered on a specified eye point with gluLookAt(). Each of these routines creates the desired matrix and applies it to the current matrix using glMultMatrix().

The glidePickMatrix() routine simplifies selection by creating a matrix that restricts drawing to a small region of the viewport. If you render the scene in selection mode after this matrix has been applied, all objects that would be drawn near the cursor will be selected and information about them stored in the selection buffer. See "Performing Selection and Feedback" earlier in this chapter for more information about selection mode.

If you need to determine where in the window an object is being drawn, use gluProject(), which converts specified coordinates from object coordinates to window coordinates; gluUnProject() performs the inverse conversion.

Polygon Tessellation
The polygon tessellation routines triangulate a concave polygon with one or more contours. To use this GLU feature, first create a tessellation object with gluNewTess(); and define callback routines that will be used to process the triangles generated by the tessellator (with gluTessCallback()). Then use gluBeginPolygon(), gluTessVertex(), gluNExtContour(), and gluEndPolygon() to specify the concave polygon to be tessellated. Unneeded tessellation objects can be destroyed with gluDeleteTess().

Rendering Spheres, Cylinders, and Disks
You can render spheres, cylinders, and disks using the GLU quadric routines. To do this, create a quadric object with gluNewQuadric(). Then specify the desired rendering style, as listed below, with the appropriate routine (unless you're satisfied with the default values):

- Whether a curve or surface should be discarded if its control polyhedron lies outside the current viewing region or whether you'll supply them explicitly with glLoadSamplingMatrices() and gluPerspective().
- Whether the projection matrix, modelview matrix, and viewport should be taken from the OpenGL server or whether you'll supply them explicitly with glLoadSamplingMatrices().
- Use gluNurbsProperty() to set these properties, or use the default values. You can query a NURBS object about its rendering style with gluNurbsProperty().

Handling Errors
The routine glGetErrorString() is provided for retrieving an error string that corresponds to an OpenGL or GLU error code. The currently defined OpenGL error codes are described in the GetError() reference page. The GLU error codes are listed in the gluErrorString(), gluQuadricCallback(), gluTessCallback(), and gluNurbsCallback() reference pages. Errors generated by GLX routines are listed in the relevant reference pages for those routines.

OpenGL Extension to the X Window System
In the X Window System, OpenGL rendering is made available as an extension to X in the formal X sense: connection and authentication are accomplished with the normal X mechanisms. As with other X
extensions, there is a defined network protocol for OpenGL's rendering commands encapsulated within the X byte stream. Since performance is critical in three-dimensional rendering, the OpenGL extension to X allows OpenGL to bypass the X server's involvement in data encoding, copying, and interpretation and instead render directly to the graphics pipeline.

This section briefly discusses the routines defined as part of GLX; these routines have the prefix glX.

Using an X Font
A shortcut for using X fonts in OpenGL is provided with the command glXUseXFont().

Chapter 3
Summary of Commands and Routines
This chapter lists the prototypes for OpenGL, the OpenGL Utility Library, and the OpenGL extension to the X Window System. The prototypes are grouped functionally, as shown below:

- OpenGL Commands
  - "Primitives"
  - "Coordinate Transformation"
  - "Coloring and Lighting"
  - "Clipping"
  - "Rasterization"
  - "Pixel Operations"
  - "Texture Mapping"
  - "Fog"
  - "Frame Buffer Operations"
  - "Evaluators"
  - "Selection and Feedback"
  - "Display Lists"
  - "Modes and Execution"
  - "State Queries"

- GLU Routines
  - "Texture Images"
  - "Coordinate Transformation"
  - "Polygon Tessellation"
  - "Quadric Objects"
  - "NURBS Curves and Surfaces"
  - "Error Handling"

- GLX Routines
  - "Initialization"
  - "Controlling Rendering"

Notation
Since some of the OpenGL commands differ from each other only by the data type of the arguments they accept, certain conventions have been used to refer to these commands in a compact way: void glVertex2{sifd}{v}(TYPE x, TYPE y);

In this example, the first set of braces encloses characters identifying the possible data types for the arguments listed as having data type TYPE. (The digit preceding the braces indicates how many arguments the command takes.) In this case, all the arguments have the placeholder TYPE, but in other situations some arguments may have an explicitly defined data type. The table shown below lists the set of possible data types, their corresponding characters, and the type definition OpenGL uses for referring to that data type.
character data type | C-language type | OpenGL type definition
---|---|---
b | 8-bit integer | signed char | GLbyte
s | 16-bit integer | short | GLshort
i | 32-bit integer | int | GLint, GLsizei
f | 32-bit floating-point | float | GLfloat
| 64-bit floating-point | double | GLdouble, GLclampd
| 8-bit unsigned integer | unsigned char | GLubyte
ub | 8-bit unsigned integer | unsigned short | GLushort
| 16-bit unsigned integer | unsigned int | GLuint, GLenum
u | 32-bit unsigned integer | void | GLvoid

Manipulate the matrix stack:
void glMatrixMode(GLenum mode);
void glPushMatrix(void);
void glPopMatrix(void);
Specify the viewport:
void glDepthRange(GLclampd near, GLclampd far);
void glViewport(GLint x, GLint y, GLsizei width, GLsizei height);

OpenGL Commands

Primitives
Specify vertices or rectangles:
void glBegin(GLenum mode);
void glEnd(void);
void glVertex2f(GLfloat x, GLfloat y);
void glVertex2fv(GLfloat v[2]);
Where the use of the vector form is ambiguous, both the vector and nonvector forms are listed. Note that not all commands with multiple arguments have a vector form and that some commands have only a vector form, in which case the v isn't enclosed in braces.

Specify a clipping plane:
void glClipPlane(GLenum plane, const GLdouble *equation);

Coordinate Transformation
Transform the current matrix:
void glRotatef(GLfloat angle, GLfloat x, GLfloat y, GLfloat z);
void glTranslatef(GLfloat x, GLfloat y, GLfloat z);
void glScalef(GLfloat x, GLfloat y, GLfloat z);
void glFrustum(GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble near, GLdouble far);
void glOrtho(GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble near, GLdouble far);
Replace the current matrix:
void glLoadMatrixf(GLfloat m[16];
void glLoadIdentity(void);

Clipping
Specify a clipping plane:
void glClipPlane(GLenum plane, const GLdouble *equation);
Return clipping plane coefficients:
void glGetClipPlane(GLenum plane, GLdouble *equation);

Rasterization
Set the current raster position:
void glVertex2f(GLfloat x, GLfloat y);
void glVertex2f(GLfloat x, GLfloat y, GLfloat z);
void glRasterPos2f(GLfloat x, GLfloat y);
void glRasterPos2f(GLfloat x, GLfloat y, GLfloat z);

Coloring and Lighting
Set the current color, color index, or normal vector:
void glColor3f(GLfloat red, GLfloat green, GLfloat blue);
void glColor4f(GLfloat red, GLfloat green, GLfloat blue, GLfloat alpha);
void glIndexf(GLfloat index);
void glNormal3f(GLfloat nx, GLfloat ny, GLfloat nz);
Specify light source, material, or lighting model parameter values:
void glLightfv(GLenum light, GLenum pname, const GLdouble *params);
void glMaterialfv(GLenum face, GLenum pname, const GLdouble *params);
void glLightModelfv(GLenum pname, const GLdouble *params);
Choose a shading model:
void glShadeModel(GLenum mode);

Set the current polygon orientation:
void glFrontFace(GLenum dir);
Cause a material color to track the current color:
void glColorMaterial(GLenum face, GLenum mode);
Obtain light source or material parameter values:
void glGetLightfv(GLenum light, GLenum pname, GLfloat *params);
void glGetMaterialfv(GLenum face, GLenum pname, GLfloat *params);

Specify which polygon orientation is front-facing:
void glFrontFace(GLenum dir);

Specify polygon edge treatment:
void glEdgeFlag(GLboolean flag);
void glEdgeFlagv(const GLboolean *flag);

Specify a bitmap:
void glBitmap(GLsizei width, GLsizei height, GLfloat xorig, GLfloat yorig, GLfloat xmove, GLfloat ymove, const GLubyte *bitmap);
Specify the dimensions of points or lines:
void glPointSize(GLfloat size);

Specify or return a stipple pattern for lines or polygons:
void glLineStipple(GLint factor, GLushort pattern);
void glGetPolygonStipple(GLubyte *mask);

Choose how polygons are rasterized:
void glCullFace(GLenum mode);
void glPolygonMode(GLenum face, GLenum mode);

Specify the dimensions of points or lines:
void glLineWidth(GLfloat width);

Pixel Operations
Select the source for pixel reads or copies:
void glReadBuffer(GLenum mode);
void glAlphaFunc(GLenum func, GLclampf ref);
void glDepthFunc(GLenum func);
void glLogiCOp(GLenum opcode);
void glClear(GLbitfield mask);
void glClearAccum(GLclampf red, GLclampf green, GLclampf blue, GLclampf alpha);
void glClearDepth(GLclampd depth);
void glClearIndex(GLclampf s);
void glClearStencil(GLint s);
Control pixel rasterization:
void glPixelZoom(GLfloat xfactor, GLfloat yfactor);
void glPixelStorei(GLenum pname, GLint param);
void glPixelMapus(GLenum map, TYPE *values);
void glPixelMapiv(GLenum map, GLint *values);
void glPixelMapfv(GLenum map, GLfloat *values);

Texture Mapping
Set the current texture coordinates:
void glTexCoord1f(GLfloat s);
void glTexCoord2f(GLfloat s, GLfloat t);
void glTexCoord3f(GLfloat s, GLfloat t, GLfloat r);
void glTexCoord4f(GLfloat s, GLfloat t, GLfloat r, GLfloat u);
Control the generation of texture coordinates:
void glTexCoordCoord{u,v}(GLSink coord);
Specify a one- or two-dimensional texture image:
void glTexImage1D(GLenum target, GLint level, GLint internalformat, GLint width, GLint border, GLint format, GLint type, const GLvoid *pixels);
void glTexImage2D(GLenum target, GLint level, GLint internalformat, GLint width, GLint height, GLint border, GLint format, GLint type, const GLvoid *pixels);
Obtain texture-related parameter values:
void glGetTexImage(GLenum target, GLint level, GLenum format, GLenum type, GLvoid *pixels);

Set the current texture coordinates:
void glTexCoord1{f,us}(GLenum coord, GLint size, GLboolean* pointer);
void glTexCoord2{f,us}(GLenum coord, GLint size, GLboolean* pointer);
void glTexCoord3{f,us}(GLenum coord, GLint size, GLboolean* pointer);
void glTexCoord4{f,us}(GLenum coord, GLint size, GLboolean* pointer);
Obtain texture-related parameter values:
void glGetTexEnvfv(GLenum target, GLenum pname, TYPE *params);
void glGetTexEnviv(GLenum target, GLenum pname, TYPE *params);
void glGetTexParameterfv(GLenum target, GLenum pname, TYPE *params);
void glGetTexParameteriv(GLenum target, GLenum pname, TYPE *params);
void glGetTexSubImage(GLenum target, GLint level, GLint internalformat, GLenum type, GLvoid *pixels);
void glGetTexImage(GLenum target, GLint level, GLenum format, GLenum type, GLvoid *pixels);
void glGetTexLevelParameterfv(GLenum target, GLint level, GLenum pname, TYPE *params);
void glGetTexLevelParameteriv(GLenum target, GLint level, GLenum pname, TYPE *params);

Fog
Set fog parameters:
void glFogfv(GLenum pname, GLvoid *params);
void glFogiv(GLenum pname, GLint *params);

Frame Buffer Operations
Control per-fragment testing:
void glScissor(GLint x, GLint y, GLsizei width, GLsizei height);
void glDepthMask(GLboolean mask);
void glBlendColor(GLenum srcRGB, GLenum srcA, GLenum dstRGB, GLenum dstA);
void glBlendAlpha(GLenum srcRGB, GLenum srcA, GLenum dstRGB, GLenum dstA);
void glBlendEquation(GLenum mode);
void glClearColor(GLclampf red, GLclampf green, GLclampf blue, GLclampf alpha);
void glClearDepthf(GLclampd depth);
void glClearIndexf(GLfloat s);
void glClearStencilf(GLfloat s);
Control buffers enabled for writing:
void glDrawBuffer(GLenum mode);
void glDepthMask(GLboolean mask);
void glColorMask(GLboolean red, GLboolean green, GLboolean blue, GLboolean alpha);
void glDepthMask(GLboolean flag);
void glAlphaFunc(GLenum func, GLclampf ref);
void glDepthFunc(GLenum func);
void glAlphaFunc(GLenum func, GLclampf ref);
void glIndexMask(GLuint mask);
void glIndexPointer(GLenum type, GLsizei stride, const GLvoid *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLbyte *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLuint *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLfloat *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLclampf *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLclampd *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLshort *pointer);
void glIndexPointer(GLenum type, GLsizei stride, const GLfloat *pointer);

Evaluators
Define a one- or two-dimensional evaluator:
void glMap1f(GLenum type, TYPE u1, TYPE u2, GLint stride, GLint order, const TYPE *points);
void glMap2f(GLenum type, TYPE u1, TYPE u2, GLint ustride, GLint uorder, TYPE v1, TYPE v2, GLint vstride);
void glMap1i(GLenum type, TYPE u1, TYPE u2, GLint stride, GLint order, const TYPE *points);
void glMap2i(GLenum type, TYPE u1, TYPE u2, GLint ustride, GLint uorder, TYPE v1, TYPE v2, GLint vstride);
GLint vorder, const TYPE *points);
Evaluate the results of a series of domain values:
void glMapGrid1(GLint n, TYPE u1, TYPE u2);
void glMapGrid2(un, TYPE u1, TYPE u2, GLint i1, TYPE v1, TYPE v2);
void glEvalMesh1(GLenum mode, GLint i1, GLint i2);
void glEvalMesh2(GLenum mode, GLint i1, GLint i2, GLint j1, GLint j2);
void glEvalPoint1(GLint i1);
void glEvalPoint2(GLint i1, GLint j1);
Evaluate one- and two-dimensional maps at a specified domain coordinate:
void glMapCoord1(fd,v)(TYPE u);
void glMapCoord2(fd,v)(TYPE u, TYPE v);
Obtain evaluator parameter values:
void glGetMap(idf)v(GLenum target, GLenum query, TYPE *v);
State Queries
Obtain information about an error or the current OpenGL connection:
GLenum glGetError(void);
const GLubyte *glGetString(GLenum name);
void glGetBooleanv(pname, GLboolean *params);
void glGetDoublev(pname, GLdouble *params);
void glGetFloatv(pname, GLfloat *params);
void glGetIntegerv(pname, GLint *params);
void glRenderMode(GLenum mode);
Save and restore sets of state variables:
void glPushAttrib(GLbitfield)
void glPassThrough(GLfloat token);
Control the name stack for selection:
void glLoadName(GLuint name);
void glPushName(GLuint name);
void glPopName(void);
void glFinish(void);
Force all issued OpenGL commands to be executed:
void glFlush(void);
Specify hints for OpenGL operation:
void glHint(GLenum target, GLenum mode);
Selection and Feedback
Control the mode and corresponding buffer:
GLint glMatrixMode(GLenum mode);
void glSelectBuffer(GLsizei size, GLuint *buffer);
void glFeedbackBuffer(GLsizei size, GLenum type);
Supplier a token for feedback mode:
void glPassThrough(GLfloat token);
Control the name stack for selection:
void glInitNames(void);
void glLoadName(GLuint name);
void glPushName(GLuint name);
void glPopName(void);
Display Lists
Create or delete display lists:
void glGenLists(GLuint base);
void glDeleteLists(GLuint list, GLsizei range);
Execute a display list or set of lists:
void glCallList(GLuint list);
void glCallLists(GLsizei n, GLenum type, void *data);
Manage display-list indices:
GLuint glGenLists(GLsizei range);
GLboolean glIsList(GLuint list);
void glListBase(GLuint base);
Coordinate Transformation
Enable, disable, and query modes:
void glEnable(GLenum cap);
void glDisable(GLenum cap);
GLboolean glIsEnabled(GLenum cap);
Wait until all OpenGL commands have executed completely:
void glFinish(void);
Translate object coordinates to screen coordinates:
void gluOrtho2D(GLdouble left, GLdouble right, GLdouble bottom, GLdouble top);
void gluPerspective(GLdouble fovy, GLdouble aspect, GLdouble zNear, GLdouble zFar);
void gluLookAt(GLdouble ex, GLdouble ey, GLdouble ez, GLdouble ox, GLdouble oy, GLdouble oz, GLdouble cx, GLdouble cy, GLdouble cz);
void glLineWidth(GLdouble width);
void glPixelZoom(GLdouble x, GLdouble y);
void glVertex2f(GLdouble x, GLdouble y);
void glVertex2i(GLint x, GLint y);
void glVertex2s(GLshort x, GLshort y);
void glVertex2d(GLdouble x, GLdouble y);
void glVertex3f(GLdouble x, GLdouble y, GLdouble z);
void glVertex3i(GLint x, GLint y, GLint z);
void glVertex3s(GLshort x, GLshort y, GLshort z);
void glVertex3d(GLdouble x, GLdouble y, GLdouble z);
void glVertex4f(GLdouble x, GLdouble y, GLdouble z, GLdouble w);
void glVertex4i(GLint x, GLint y, GLint z, GLint w);
void glVertex4s(GLshort x, GLshort y, GLshort z, GLshort w);
void glVertex4d(GLdouble x, GLdouble y, GLdouble z, GLdouble w);
void glBlendFunc(GLenum sfactor, GLenum dfactor);
void glBlendFuncSeparate(GLenum srcRGB, GLenum dstRGB, USEGLboolean srcAlpha, USEGLboolean dstAlpha);
Use a blend function to modulate color:
void glBlendEquation(GLenum mode);
void glBlendEquationSeparate(GLenum modeRGB, GLenum modeAlpha);
Texture Images
Magnify or shrink an image:
int gluScaleImage(GLenum format, GLint widthin, GLint heightin, GLenum typein, const void *datain, GLint widthout, GLint heightout, GLenum typeout, dataout);
Create mipmaps for an image:
int gluBuild1DMipmaps(GLenum target, GLint components, GLint width, GLenum format, void *data);
int gluBuild2DMipmaps(GLenum target, GLint components, GLint width, GLint height, GLenum format, void *data);
Generate mipmaps for an image:
int gluBuild1DMipmaps(GLenum target, GLint components, GLint width, GLuint base, GLenum format, void *data);
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void gluLookAt(GLdouble ex, GLdouble ey, GLdouble ez, GLdouble ox, GLdouble oy, GLdouble oz, GLdouble cx, GLdouble cy, GLdouble cz);
void glLineWidth(GLdouble width);
void glPixelZoom(GLdouble x, GLdouble y);
void glVertex2f(GLdouble x, GLdouble y);
void glVertex2i(GLint x, GLint y);
void glVertex2s(GLshort x, GLshort y);
void glVertex2d(GLdouble x, GLdouble y);
void glVertex3f(GLdouble x, GLdouble y, GLdouble z);
void glVertex3i(GLint x, GLint y, GLint z);
void glVertex3s(GLshort x, GLshort y, GLshort z);
void glVertex3d(GLdouble x, GLdouble y, GLdouble z);
void glVertex4f(GLdouble x, GLdouble y, GLdouble z, GLdouble w);
void glVertex4i(GLint x, GLint y, GLint z, GLint w);
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int gluBuild2DMipmaps(GLenum target, GLint components, GLint width, GLint height, GLuint base, GLenum format, void *data);
Polygon Tessellation
Manage tessellation objects:
GLUtriangulatorObj * gluNewTess (void);
void gluTessCallback (GLUtriangulatorObj * tobj, GLenum which, void (* fn));
void gluDeleteTess (GLUtriangulatorObj * tobj);

Describe the input polygon:
void gluBeginPolygon (GLUtriangulatorObj * tobj);
void gluEndPolygon (GLUtriangulatorObj * tobj);
void gluTessVertex (GLUtriangulatorObj * tobj, GLdouble x[3], void * data);

Quadric Objects
Manage quadric objects:
GLUquadricObj * gluNewQuadric (void);
void gluDeleteQuadric (GLUquadricObj * qobj);
void gluQuadricNormals (GLUquadricObj * quadObject, GLenum normals);
void gluQuadricTexture (GLUquadricObj * quadObject, GLboolean textureCoords);
void gluQuadricOrientation (GLUquadricObj * quadObject, GLenum orientation);
void gluQuadricDrawStyle (GLUquadricObj * quadObject, GLenum drawStyle);
void gluQuadricProperty (GLUquadricObj * qobj, GLenum property);

NURBS Curves and Surfaces
Manage a NURBS object:
GLUnurbsObj * gluNewNurbsRenderer (void);
void gluDeleteNurbsRenderer (GLUnurbsObj * nobj);
void gluNurbsCallback (GLUnurbsObj * nobj, GLenum which, void (* fn));

Create a NURBS curve:
void gluBeginCurve (GLUnurbsObj * nobj);
void gluEndCurve (GLUnurbsObj * nobj);
void gluNurbsCurve (GLUnurbsObj * nobj, GLint nknots, GLfloat * knot, GLint stride, GLdouble * tarray, GLint order, GLenum type);

Create a NURBS surface:
void gluBeginSurface (GLUnurbsObj * nobj);
void gluEndSurface (GLUnurbsObj * nobj);

void gluNurbsSurface (GLUnurbsObj * nobj, GLint uknot_count, GLfloat * knot, GLint vstride, GLdouble * tarray, GLint order, GLenum type);

Define a trimming region:
void gluBeginTrim (GLUnurbsObj * nobj);
void gluEndTrim (GLUnurbsObj * nobj);
void gluPwlCurve (GLUnurbsObj * nobj, GLint jcount, GLfloat * array, GLint stride, GLenum type);

Manage tessellation objects:
void gluLoadSamplingMatrices (GLUnurbsObj * nobj, const GLfloat * modelMatrix);
void gluBeginTriangulation (GLUnurbsObj * nobj);
void gluEndTriangulation (GLUnurbsObj * nobj);
void gluPartialDisk (GLUnurbsObj * nobj, GLint slices, GLint loops, GLint startAngle, GLint sweepAngle);

Quadric Objects
Manage quadric objects:
GLUquadricObj * gluNewQuadric (void);
void gluDeleteQuadric (GLUquadricObj * qobj);
void gluQuadricNormals (GLUquadricObj * quadObject, GLenum normals);
void gluQuadricTexture (GLUquadricObj * quadObject, GLboolean textureCoords);
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void gluBeginTrim (GLUnurbsObj * nobj);
void gluEndTrim (GLUnurbsObj * nobj);
void gluPwlCurve (GLUnurbsObj * nobj, GLint jcount, GLfloat * array, GLint stride, GLenum type);

Control NURBS rendering:
void gluLoadSamplingMatrices (GLUnurbsObj * nobj, const GLfloat * modelMatrix); const GLdouble * progMatrix[16], const GLint viewport[4]);
void gluNurbsProperty (GLUnurbsObj * nobj, GLenum property, GLfloat float * value);

Error Handling
Produce an error string from an OpenGL error code:
const GLubyte * gluErrorString (GLenum errorcode);

GLX Routines
Initialization
Determine whether the GLX extension is defined on the X server:
Bool glXQueryExtension (Display * dpy, int * errorBase, int * errorBase);

Obtain the desired visual:
XVisualInfo * glXChooseVisual (Display * dpy, int screen, int * attribList);
int glXGetConfig (Display * dpy, XVisualInfo * vis, int attrib, int * value);

Controlling Rendering
Manage or query an OpenGL rendering context:
GLXContext glXGetCurrentContext (void);
GLXContext glXCreateContext (Display * dpy, XVisualInfo * vis, GLXContext sharedList, Bool direct);
void glXDestroyContext (Display * dpy, GLXContext context);
void glXCopyContext (Display * dpy, GLXContext src, GLXContext dst, GLuint mask);
 Bool glXIsDirect (Display * dpy, GLXContext context);
Bool glXMakeCurrent (Display * dpy, GLXDrawable drawable, GLXContext context);
GLXContext glXGetCurrentContext (void);
GLXDrawable glXGetCurrentDrawable (void);

Perform off−screen rendering:
GLXPixmap glXCreateGLXPixmap (Display * dpy, XVisualInfo * vis, Pixmap pixmap);
void glXDestroyGLXPixmap (Display * dpy, GLXPixmap pix);

Synchronize execution:
void glXWaitGL (void);
void glXWaitX (void);
### Chapter 4

**Defined Constants and Associated Commands**

This chapter lists all the defined constants in OpenGL and their corresponding commands; these constants might indicate a parameter name, a value for a parameter, a mode, a query target, or a return value. The list is intended to be used as another index into the reference pages: if you remember the name of a constant, you can use this table to find out which functions use it, and then you can refer to the reference pages for those functions for more information. Note that all the constants listed can be used directly by the corresponding commands; the reference pages list additional, related commands that might be of interest.

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</tr>
<tr>
<td>GL_COLOR_INDEX</td>
<td>glGet*()</td>
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<tr>
<td>GL_COLOR_INDEXES</td>
<td>glGet*()</td>
</tr>
<tr>
<td>GL_COLOR_MATERIAL</td>
<td>glGet*()</td>
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<tr>
<td>GL_COLOR_MATERIAL_FACE</td>
<td>glGet*()</td>
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<tr>
<td>GL_COLOR_MATERIAL_PARAMETER</td>
<td>glGet*()</td>
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<tr>
<td>GL_COLOR_MATERIAL_FACE</td>
<td>glGet*()</td>
</tr>
<tr>
<td>GL_COLOR_MATERIAL_PARAMETER</td>
<td>glGet*()</td>
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<td>GL_COLOR_WRITEMASK</td>
<td>glGet*()</td>
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<tr>
<td>GL_COMPILE</td>
<td>glGet*()</td>
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<tr>
<td>GL_COMPILE_AND_EXECUTE</td>
<td>glGet*()</td>
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<tr>
<td>GL_CONSTANT_ATTENUATION</td>
<td>glGet*()</td>
</tr>
<tr>
<td>GL_CURRENT_COLOR, GL_CURRENT_INDEX, GL_CURRENT_NORMAL, GL_CURRENT_RASTER_COLOR, GL_CURRENT_RASTER_INDEX, GL_CURRENT_RASTER_POSITION, GL_CURRENT_RASTER_POSITION_VALID, GL_CURRENT_RASTER_TEXTURE_COORDS, GL_CURRENT_TEXTURE_COORDS</td>
<td>glGet*()</td>
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<td>GL_DECAL</td>
<td>glGet*()</td>
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<tr>
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<td>glGet*()</td>
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<td>glGet*()</td>
</tr>
<tr>
<td>GL_DEPTH_BITS</td>
<td>glGet*()</td>
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</table>
Chapter 5
OpenGL Reference Pages
This chapter contains the reference pages, in alphabetical order, for all the OpenGL commands. Each reference page may describe more than one related command, as shown in the following list of pages. The OpenGL Utility Library routines and those comprising the OpenGL extension to the X Window System are described in the following chapters.

glAccum

NAME


The accumulation buffer is an extended-range color buffer. Images are not rendered into it. Rather, images rendered into one of the color buffers are added to the contents of the accumulation buffer after rendering. Effects such as anti-aliasing (of points, lines, and polygons), motion blur, and depth of field can be created by accumulating images generated with different transformation matrices.

Each pixel in the accumulation buffer consists of red, green, blue, and alpha values. The number of bits per component in the accumulation buffer depends on the implementation. You can examine this number by calling glGetInteger four times, with arguments GL_ACCUM_RED_BITS, GL_ACCUM_GREEN_BITS, GL_ACCUM_BLUE_BITS, and GL_ACCUM_ALPHA_BITS, respectively. Regardless of the number of bits per component, however, the range of values stored by each component is \([-1, 1]\]. The accumulation buffer pixels are mapped one-to-one with frame buffer pixels.

All accumulation buffer operations are limited to the area of the current scissor box and are applied identically to the red, green, blue, and alpha components of each pixel. The contents of an accumulation buffer pixel component are undefined if the glAccum operation results in a value outside the range \([-1, 1]\). The operations are as follows:

**glAccum**

- **void glAccum** (GLenum op, GLfloat value)

**PARAMETERS**

- **op** Specifies the accumulation buffer operation. Symbolic constants GL_ACCUM, GL_LOAD, GL_ADD, GL_MULT, and GL_RETURN are accepted.
- **value** Specifies a floating-point value used in the accumulation buffer operation. op determines how value is used.

**DESCRIPTION**

The accumulation buffer is cleared by specifying R, G, B, and A values to set it to the

**NOTES**

Only those pixels within the current scissor box are updated by any glAccum operation.

**ERRORS**

- GL_INVALID_ENUM is generated if op is not an accepted value.
- GL_INVALID_OPERATION is generated if there is no accumulation buffer.

**ASSOCIATED GETS**

- glGet with argument GL_ACCUM_RED_BITS
- glGet with argument GL_ACCUM_GREEN_BITS
- glGet with argument GL_ACCUM_BLUE_BITS
- glGet with argument GL_ACCUM_ALPHA_BITS

**SEE ALSO**

- glBlendFunc
- glClear
- glClearAccum
- glCopyPixels
- glGet
- glLogicOp
- glPixelStore
- glPixelTransfer
- glReadPixels
- glReadBuffer
- glScissor
- glStencilOp

**glAlphaFunc**

**NAME**

- glAlphaFunc — specify the alpha test function

**C SPECIFICATION**

- void glAlphaFunc (GLenum func, GLclampf ref)

**PARAMETERS**

- **func** Specifies the alpha comparison function. Symbolic constants GL_NEVER, GL_LESS, GL_EQUAL, GL LEQUAL, GL_GREATER, GL_NOTEQUAL, and GL_ALWAYS are accepted. The default function is GL_ALWAYS.
- **ref** Specifies the reference value that incoming alpha values are compared to. This value is clamped to the range 0 through 1, where 0 represents the lowest possible alpha value and 1 the highest possible value. The default reference is 0.

**DESCRIPTION**

The alpha test discards fragments depending on the outcome of a comparison between the incoming fragment's alpha value and a constant reference value. glAlphaFunc specifies the reference and comparison function. The comparison is performed only if alpha testing is enabled. (See glEnable and glDisable of GL_ALPHA_TEST.)

func and ref specify the conditions under which the pixel is drawn. The incoming alpha value is compared to ref using the function specified by func. If the comparison passes, the incoming fragment is drawn, conditional on subsequent stencil and depth buffer tests. If the comparison fails, no change is
made to the frame buffer at that pixel location.
The comparison functions are as follows:

- **GL_NEVER**: Never passes.
- **GL_LESS**: Passes if the incoming alpha value is less than the reference value.
- **GL_EQUAL**: Passes if the incoming alpha value is equal to the reference value.
- **GL_LEQUAL**: Passes if the incoming alpha value is less than or equal to the reference value.
- **GL_GREATER**: Passes if the incoming alpha value is greater than the reference value.
- **GL_GEQUAL**: Passes if the incoming alpha value is greater than or equal to the reference value.
- **GL_NOTEQUAL**: Passes if the incoming alpha value is not equal to the reference value.
- **GL_ALWAYS**: Always passes.

`glAlphaFunc` operates on all pixel writes, including those resulting from the scan conversion of points, lines, polygons, and bitmaps, and from pixel draw and copy operations. `glAlphaFunc` does not affect screen clear operations.

### NOTES
Alpha testing is done only in RGBA mode.

### ERRORS
- **GL_INVALID_ENUM** is generated if `func` is not an accepted value.
- **GL_INVALID_OPERATION** is generated if `glAlphaFunc` is called between a call to `glBegin` and the corresponding call to `glEnd`.

### ASSOCIATED GETS
- `glGet` with argument **GL_ALPHA_TEST_FUNC**
- `glGet` with argument **GL_ALPHA_TEST_REF**
- `glIsEnabled` with argument **GL_ALPHA_TEST**

### SEE ALSO
- `glBlendFunc`, `glClear`, `glDepthFunc`, `glEnable`, `glStencilFunc`

### NAME
`glBegin`, `glEnd` — delimit the vertices of a primitive or a group of like primitives

### C SPECIFICATION
```c
void glEnd(void)
```

### DESCRIPTION
`glBegin` and `glEnd` delimit the vertices that define a primitive or a group of like primitives. `glBegin` accepts a single argument that specifies which of ten ways the vertices are interpreted. Taking as an integer count starting at one, and `N` as the total number of vertices specified, the interpretations are as follows:

- **GL_POINTS**: Treats each vertex as a single point. Vertex `n` defines point `n`. `N` points are drawn.
- **GL_LINES**: Treats each pair of vertices as an independent line segment. Vertices `2n−1` and `2n` define line `n`. `N/2` lines are drawn.
- **GL_LINE_STRIP**: Draws a connected group of line segments from the first vertex to the last. Vertices `n` and `n+1` define line `n`. `N−1` lines drawn.
- **GL_LINE_LOOP**: Draws a connected group of line segments from the first vertex to the last, then back to the first. Vertices `n` and `n+1` define line `n`. The last line, however, is defined by vertices `N` and 1. `N` lines are drawn.
- **GL_TRIANGLES**: Treats each triplet of vertices as an independent triangle. Vertices `3n−2`, `3n−1`, and `3n` define triangle `n`. `N/3` triangles are drawn.
- **GL_TRIANGLE_STRIP**: Draws a connected group of triangles. One triangle is defined for each vertex presented after the first two vertices. For odd `n`, vertices `n`, `n+1`, and `n+2` define triangle `n`. For even `n`, vertices `n−1`, `n`, and `n+2` define triangle `n`. `N−2` triangles are drawn.
- **GL_TRIANGLE_FAN**: Draws a connected group of triangles. One triangle is defined for each vertex presented after the first two vertices. Vertices `4n−1`, `4n−3`, `4n−2`, and `4n` define quadrilateral `n`. `N/4` quadrilaterals are drawn.
- **GL_QUADS**: Treats each group of four vertices as an independent quadrilateral. Vertices `4n−3`, `4n−2`, `4n−1`, and `4n` define quadrilateral `n`. `N/4` quadrilaterals are drawn.
- **GL_QUAD_STRIP**: Draws a connected group of quadrilaterals. One quadrilateral is defined for each pair of vertices presented after the first pair. Vertices `2n−1`, `2n`, `2n+2`, and `2n+1` define quadrilateral `n`. `N/2−1` quadrilaterals are drawn. Note that the order in which vertices are used to construct a quadrilateral from strip data is different from that used with independent data.
- **GL_POLYGON**: Draws a single, convex polygon. Vertices 1 through `N` define this polygon.

Only a subset of GL commands can be used between `glBegin` and `glEnd`. The commands are `glVertex`, `glColor`, `glIndex`, `glNormal`, `glTexCoord`, `glEvalCoord`, `glEvalPoint`, `glMaterial`, and `glEdgeFlag`. Also, it is acceptable to use `glCallList` or `glCallLists` to execute display lists that include only the preceding commands. If any other GL command is called between `glBegin` and `glEnd`, the error flag is set and the command is ignored.

Regardless of the value chosen for mode, there is no limit to the number of vertices that can be defined between `glBegin` and `glEnd`. Lines, triangles, quadrilaterals, and polygons that are incompletely specified are not drawn. Incomplete specification results when either too few vertices are provided to specify even a single primitive or when an incorrect multiple of vertices is specified. The incomplete primitive is ignored; the rest are drawn.
The minimum specification of vertices for each primitive is as follows: 1 for a point, 2 for a line, 3 for a triangle, 4 for a quadrilateral, and 3 for a polygon. Modes that require a certain multiple of vertices are `GL_LINES` (2), `GL_TRIANGLES` (3), `GL_QUADS` (4), and `GL_QUAD_STRIP` (2).

ERRORS

GL_INVALID_ENUM is generated if mode is set to an unaccepted value.

GL_INVALID_OPERATION is generated if a command other than glVertex, glColor, glindex, glNormal, glTexCoord, glEvalCoord, glEvalPoint, glMaterial, glEdgeFlag, glCallLists or glCallList is called between glBegin and the corresponding glEnd.

GL_INVALID_OPERATION is generated if glEnd is called before the corresponding glBegin is called, or if glBegin is called within a glBegin/glEnd sequence.

SEE ALSO

`glList`, `glList`, `glColor`, `glEdgeFlag`, `glEvalCoord`, `glEvalPoint`, `glIndex`, `glMaterial`, `glNormal`, `glTexCoord`.

`glBitmap` — draw a bitmap

C SPECIFICATION

```c
void glBitmap( GLsizei width, GLsizei height, GLfloat xorig, GLfloat yorig, GLfloat xmove, GLfloat ymove, const GLubyte *bitmap )
```

PARAMETERS

- `width`, `height`: Specify the pixel width and height of the bitmap image.
- `xorig`, `yorig`: Specify the location of the origin in the bitmap image. The origin is measured from the lower left corner of the bitmap, with right and up being the positive axes.
- `xmove`, `ymove`: Specify the x and y offsets to be added to the current raster position after the bitmap is drawn.
- `bitmap`: Specifies the address of the bitmap image.

DESCRIPTION

A bitmap is a binary image. When drawn, the bitmap is positioned relative to the current raster position, and frame buffer pixels corresponding to ones in the bitmap are written using the current raster color or index. Frame buffer pixels corresponding to zeros in the bitmap are not modified.

`glBitmap` takes seven arguments. The first pair specify the width and height of the bitmap image. The second pair specify the location of the bitmap origin relative to the lower left corner of the bitmap image. The third pair of arguments specify the x and y offsets to be added to the current raster position after the bitmap has been drawn. The final argument is a pointer to the bitmap image itself.

The bitmap image is interpreted like image data for the `glDrawPixels` command, with width and height corresponding to the width and height arguments of that command, and with type set to `GL_BITMAP` and format set to `GL_COLOR_INDEX`. Modes specified using `glPixelStore` affect the interpretation of bitmap image data; modes specified using `glPixelTransfer` do not.

If the current raster position is invalid, `glBitmap` is ignored. Otherwise, the lower left corner of the bitmap image is positioned at the window coordinates

\[
\begin{align*}
x_w &= x_r - x_o \\
y_w &= y_r - y_o
\end{align*}
\]

where \((x_r, y_r)\) is the raster position and \((x_o, y_o)\) is the bitmap origin. Fragments are then generated for each pixel corresponding to a one in the bitmap image. These fragments are generated using the current raster z coordinate, color or color index, and current raster texture coordinates. They are then treated just as if they had been generated by a point, line, or polygon, including texture mapping, fogging, and all per-fragment operations such as alpha and depth testing.

After the bitmap has been drawn, the x and y coordinates of the current raster position are offset by `xmove` and `ymove`. No change is made to the z coordinate of the current raster position, or to the current raster color, index, or texture coordinates.

ERRORS

GL_INVALID_VALUE is generated if width or height is negative.

GL_INVALID_OPERATION is generated if `glBitmap` is called between a call to `glBegin` and the corresponding call to `glEnd`.

ASSOCIATED GETS

`glGet` with argument `GL_CURRENT_RASTER_POSITION`, `GL_CURRENT_RASTER_COLOR`, `GL_CURRENT_RASTER_INDEX`, `GL_CURRENT_RASTER_TEXTURE_COORDS`, `GL_CURRENT_RASTER_POSITION_VALID`.

SEE ALSO

`glDrawPixels`, `glRasterPos`, `glPixelStore`, `glPixelTransfer`.

`glEnable` — enable pixel arithmetic

C SPECIFICATION

```c
void glEnable( GLenum flag )
```

PARAMETERS

- `flag`: Specifies the pixel arithmetic function to be enabled.

NAME

`glEnable` — enable pixel arithmetic
Nine symbolic constants are accepted: GL_ZERO, GL_ONE, GL_DST_COLOR, GL_ONE_MINUS_DST_COLOR, GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA, GL_SRC_COLOR, GL_ONE_MINUS_SRC_COLOR, GL_SRC_ALPHA_SATURATE.

dfactor

Specifies how the red, green, blue, and alpha destination blending factors are computed. Eight symbolic constants are accepted: GL_ZERO, GL_ONE, GL_SRC_COLOR, GL_ONE_MINUS_SRC_COLOR, GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA, GL_DST_COLOR, GL_ONE_MINUS_DST_COLOR, and GL_SRC_ALPHA_SATURATE.

DESCRIPTION

In RGB mode, pixels can be drawn using a function that blends the incoming (source) RGBA values with the RGBA values that are already in the frame buffer (the destination values). By default, blending is disabled. Use glEnable and glDisable with argument GL_BLEND to enable and disable blending.

glBlendFunc defines the operation of blending when it is enabled. sfactor specifies which of nine methods is used to scale the source color components. dfactor specifies which of eight methods is used to scale the destination color components. The eleven possible methods are described in the table below. Each method defines four scale factors, one each for red, green, blue, and alpha.

In the table and in subsequent equations, source and destination color components are referred to as (R, G, B, A) and (Rd, Gd, Bd, Ad). They are understood to have integer values between zero and (kR, kG, kB, kA), where

\[ k_c = 2^{m_c} - 1 \]

and \((m_R, m_G, m_B, m_A)\) is the number of red, green, blue, and alpha bitplanes. Source and destination scale factors are referred to as (sR, sG, sB, sA) and (dR, dG, dB, dA). The scale factors described in the table, denoted (fR, fG, fB, fA), represent either source or destination factors. All scale factors have range [0,1].

<table>
<thead>
<tr>
<th>parameter</th>
<th>((f_R, f_G, f_B, f_A))</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL_ZERO</td>
<td>(0, 0, 0, 0)</td>
</tr>
<tr>
<td>GL_ONE</td>
<td>(1, 1, 1, 1)</td>
</tr>
<tr>
<td>GL_SRC_COLOR</td>
<td>(R_s / kR, G_s / kG, B_s / kB, A_s / kA)</td>
</tr>
<tr>
<td>GL_ONE_MINUS_SRC_COLOR</td>
<td>(1, 1, 1, 1) − (R_s / kR, G_s / kG, B_s / kB, A_s / kA)</td>
</tr>
<tr>
<td>GL_DST_COLOR</td>
<td>(R_d / kR, G_d / kG, B_d / kB, A_d / kA)</td>
</tr>
<tr>
<td>GL_ONE_MINUS_DST_COLOR</td>
<td>(1, 1, 1, 1) − (R_d / kR, G_d / kG, B_d / kB, A_d / kA)</td>
</tr>
<tr>
<td>GL_SRC_ALPHA</td>
<td>(A_s / kA, A_s / kA, A_s / kA, A_s / kA)</td>
</tr>
<tr>
<td>GL_ONE_MINUS_SRC_ALPHA</td>
<td>(1, 1, 1, 1) − (A_s / kA, A_s / kA, A_s / kA, A_s / kA)</td>
</tr>
<tr>
<td>GL_DST_ALPHA</td>
<td>(A_d / kA, A_d / kA, A_d / kA, A_d / kA)</td>
</tr>
<tr>
<td>GL_ONE_MINUS_DST_ALPHA</td>
<td>(1, 1, 1, 1) − (A_d / kA, A_d / kA, A_d / kA, A_d / kA)</td>
</tr>
<tr>
<td>GL_SRC_ALPHA_SATURATE</td>
<td>(i, i, i, 1)</td>
</tr>
</tbody>
</table>

In the table,

\[ i = \min (k_A, k_A - A_d) / k_A \]

To determine the blended RGBA values of a pixel when drawing in RGB mode, the system uses the following equations:

\[ R_d = \min (k_R, R_s + R_d \cdot d_R) \]
\[ G_d = \min (k_G, G_s + G_d \cdot d_G) \]
\[ B_d = \min (k_B, B_s + B_d \cdot d_B) \]
\[ A_d = \min (k_A, A_s + A_d \cdot d_A) \]

Despite the apparent precision of the above equations, blending arithmetic is not exactly specified, because blending operates with imprecise integer color values. However, a blend factor that should be equal to one is guaranteed not to modify its multiplicand, and a blend factor equal to zero reduces its multiplicand to zero. Thus, for example, when sfactor is GL_SRC_ALPHA, dfactor is GL_ONE_MINUS_DST_ALPHA, and As is equal to A, the equations reduce to simple replacement:

\[ R_d = R_s \]
\[ G_d = G_s \]
\[ B_d = B_s \]
\[ A_d = A_s \]

EXAMPLES

Transparency is best implemented using blend function (GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA) with primitives sorted from farthest to nearest. Note that this transparency calculation does not require the presence of alpha bitplanes in the frame buffer. Blend function (GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA) is also useful for rendering antialiased points and lines in arbitrary order. Polygon antialiasing is optimized using blend function (GL_SRC_ALPHA_SATURATE, GL_ONE) with polygons sorted from nearest to farthest. (See the "glEnable" and "glDisable" reference page and the GL_POLYGON_SMOOTH argument for information on polygon antialiasing.) Destination alpha bitplanes, which must be present for this blend function to operate correctly, store the accumulated coverage.

NOTES

Incoming (source) alpha is correctly thought of as a material opacity, ranging from 1.0 (1), representing complete opacity, to 0.0 (0), representing completely transparency.

When more than one color buffer is enabled for drawing, blending is done separately for each enabled buffer, using for destination color the contents of that buffer. (See "glDrawBuffers".)

Blending affects only RGB rendering. It is ignored by color index renderers.

ERRORS

GL_INVALID_ENUM is generated if either sfactor or dfactor is not an accepted value.

GL_INVALID_OPERATION is generated if glBlendFunc is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

glGet with argument GL_BLEND_SRC

glGet with argument GL_BLEND_DST

glIsEnabled with argument GL_BLEND

SEE ALSO

"glAlphaFunc", "glClearColor", "glDrawBuffer", "glEnable", "glLogicOp", "glStencilFunc"
**glCallList**

**NAME**

`glCallList` — execute a display list

**C SPECIFICATION**

```c
void glCallList( GLuint list )
```

**PARAMETERS**

- `list` Specifies the integer name of the display list to be executed.

**DESCRIPTION**

`glCallList` causes the named display list to be executed. The commands saved in the display list are executed in order, just as if they were called without using a display list. If `list` has not been defined as a display list, `glCallList` is ignored.

`glCallList` can appear inside a display list. To avoid the possibility of infinite recursion resulting from display lists calling one another, a limit is placed on the nesting level of display lists during display-list execution. This limit is at least 64, and it depends on the implementation.

GL state is not saved and restored across a call to `glCallList`. Thus, changes made to GL state during the execution of a display list remain after execution of the display list is completed. Use `glPushAttrib`, `glPopAttrib`, `glPushMatrix`, and `glPopMatrix` to preserve GL state across `glCallList` calls.

**NOTES**

Display lists can be executed between a call to `glBegin` and the corresponding call to `glEnd`, as long as the display list includes only commands that are allowed in this interval.

**ASSOCIATED GETS**

- `glGet` with argument `GL_MAX_LIST_NESTING`
- `glListBase`

**SEE ALSO**

- `glCallLists`, `glDeleteLists`, `glGenLists`, `glNewList`, `glPushAttrib`, `glPushMatrix`

---

**glCallLists**

**NAME**

`glCallLists` — execute a list of display lists

**C SPECIFICATION**

```c
void glCallLists( GLsizei n, GLenum type, const GLvoid *lists )
```

**PARAMETERS**

- `n` Specifies the number of display lists to be executed.
- `type` Specifies the type of values in lists. Symbolic constants `GL_BYTE`, `GL_UNSIGNED_BYTE`, `GL_SHORT`, `GL_UNSIGNED_SHORT`, `GL_INT`, `GL_UNSIGNED_INT`, `GL_FLOAT`, `GL_2_BYTES`, `GL_3_BYTES`, and `GL_4_BYTES` are accepted.
- `lists` Specifies the address of an array of name offsets in the display list. The pointer type is void because the offsets can be bytes, shorts, ints, or floats, depending on the value of `type`.

**DESCRIPTION**

`glCallLists` causes each display list in the list of names passed as lists to be executed. As a result, the commands saved in each display list are executed in order, just as if they were called without using a display list. Names of display lists that have not been defined are ignored.

`glCallLists` provides an efficient means for executing display lists. `n` allows lists with various name formats to be accepted. The formats are as follows:

- `GL_BYTE` lists is treated as an array of signed bytes, each in the range −128 through 127.
- `GL_UNSIGNED_BYTE` lists is treated as an array of unsigned bytes, each in the range 0 through 255.
- `GL_SHORT` lists is treated as an array of signed two-byte integers, each in the range −32768 through 32767.
- `GL_UNSIGNED_SHORT` lists is treated as an array of unsigned two-byte integers, each in the range 0 through 65535.
- `GL_INT` lists is treated as an array of signed four-byte integers.
- `GL_UNSIGNED_INT` lists is treated as an array of unsigned four-byte integers.
- `GL_FLOAT` lists is treated as an array of four-byte floating-point values.
- `GL_2_BYTES` lists is treated as an array of unsigned bytes. Each pair of bytes specifies a single display-list name. The value of the pair is computed as 256 times the unsigned value of the first byte plus the unsigned value of the second byte.
- `GL_3_BYTES` lists is treated as an array of unsigned bytes. Each triplet of bytes specifies a single display-list name. The value of the triplet is computed as 65536 times the unsigned value of the first byte, plus 256 times the unsigned value of the second byte, plus the unsigned value of the third byte.
- `GL_4_BYTES` lists is treated as an array of unsigned bytes. Each quadruplet of bytes specifies a single display-list name. The value of the quadruplet is computed as 16777216 times the unsigned value of the first byte, plus 65536 times the unsigned value of the second byte, plus 256 times the unsigned value of the third byte, plus the unsigned value of the fourth byte.

The list of display list names is not null-terminated. Rather, `n` specifies how many names are to be taken from `lists`.

An additional level of indirection is made available with the `glListBase` command, which specifies an unsigned offset that is added to each display-list name specified in `lists` before that display list is executed.

`glCallLists` can appear inside a display list. To avoid the possibility of infinite recursion resulting from display lists calling one another, a limit is placed on the nesting level of display lists during display-list execution. This limit must be at least 64, and it depends on the implementation.

GL state is not saved and restored across a call to `glCallLists`. Thus, changes made to GL state during the execution of the display lists remain after execution is completed. Use `glPushAttrib`, `glPopAttrib`, `glPushMatrix`, and `glPopMatrix` to preserve GL state across `glCallLists` calls.
NOTES
Display lists can be executed between a call to glBegin and the corresponding call to glEnd, as long as the display list includes only commands that are allowed in this interval.

ASSOCIATED GETS
 glGet with argument GL_LIST_BASE
 glGet with argument GL_MAX_LIST_NESTING
 glEnd

SEE ALSO

glClear

NAME
glClear — clear buffers within the viewport

C SPECIFICATION
void glClear( GLbitfield mask )

PARAMETERS
mask Bitwise OR of masks that indicate the buffers to be cleared. The four masks are
GL_COLOR_BUFFER_BIT, GL_DEPTH_BUFFER_BIT, GL_ACCUM_BUFFER_BIT, and GL_STENCIL_BUFFER_BIT.

DESCRIPTION
glClear sets the bitplane area of the window to values previously selected by glClearColor, glClearIndex, glClearDepth, glClearStencil, and glClearAccum. Multiple color buffers can be cleared simultaneously by selecting more than one buffer at a time using glDrawBuffer.

The pixel ownership test, the scissor test, dithering, and the buffer writemasks affect the operation of glClear. The scissor box bounds the cleared region. Alpha function, blend function, logical operation, stencilizing, texture mapping, and z-buffering are ignored by glClear.

glClear takes a single argument that is the bitwise OR of several values indicating which buffer is to be cleared.

The values are as follows:
GL_COLOR BUFFER BIT Indicates the buffers currently enabled for color writing.
GL_DEPTH BUFFER BIT Indicates the depth buffer.
GL_ACCUM BUFFER BIT Indicates the accumulation buffer.
GL_STENCIL BUFFER BIT Indicates the stencil buffer.

The value to which each buffer is cleared depends on the setting of the clear value for that buffer.

NOTES
If a buffer is not present, then a glClear directed at that buffer has no effect.

ERRORS
GL_INVALID_VALUE is generated if any bit other than the four defined bits is set in mask.
GL_INVALID_OPERATION is generated if glClear is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
 glGet with argument GL_ACCUM_CLEAR_VALUE
 glGet with argument GL_DEPTH_CLEAR_VALUE
 glGet with argument GL_INDEX_CLEAR_VALUE
 glGet with argument GL_COLOR_CLEAR_VALUE
 glGet with argument GL_STENCIL_CLEAR_VALUE

SEE ALSO

glClearAccum

NAME
glClearAccum — specify clear values for the accumulation buffer

C SPECIFICATION
void glClearAccum( GLfloat red, GLfloat green, GLfloat blue, GLfloat alpha )

PARAMETERS
red, green, blue, alpha Specify the red, green, blue, and alpha values used when the accumulation buffer is cleared. The default values are all zero.

DESCRIPTION
glClearAccum specifies the red, green, blue, and alpha values used by glClear to clear the accumulation buffer.

Values specified by glClearAccum are clamped to the range [−1,1].

ERRORS
GL_INVALID_OPERATION is generated if glClearAccum is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
 glGet with argument GL_ACCUM_CLEAR_VALUE
SEE ALSO
'glClear''

**glClearColor**

**NAME**
glClearColor — specify clear values for the color buffers

**C SPECIFICATION**

```c
void glClearColor( GLclampf red, GLclampf green, GLclampf blue, GLclampf alpha )
```

**PARAMETERS**

- `red`, `green`, `blue`, `alpha`

Specify the red, green, blue, and alpha values used when the color buffers are cleared.

The default values are all zero.

**DESCRIPTION**

`glClearColor` specifies the red, green, blue, and alpha values used by `glClear` to clear the color buffers. Values specified by `glClearColor` are clamped to the range [0,1].

**ERRORS**

- `GL_INVALID_OPERATION` is generated if `glClearColor` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- glGet with argument `GL_COLOR_CLEAR_VALUE`

SEE ALSO

- 'glClear''

**glClearDepth**

**NAME**
glClearDepth — specify the clear value for the depth buffer

**C SPECIFICATION**

```c
void glClearDepth( GLclampd depth )
```

**PARAMETERS**

- `depth`

Specifies the depth value used when the depth buffer is cleared.

**DESCRIPTION**

`glClearDepth` specifies the depth value used by `glClear` to clear the depth buffer. Values specified by `glClearDepth` are clamped to the range [0,1].

**ERRORS**

- `GL_INVALID_OPERATION` is generated if `glClearDepth` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- glGet with argument `GL_DEPTH_CLEAR_VALUE`

SEE ALSO

- 'glClear''

**glClearIndex**

**NAME**
glClearIndex — specify the clear value for the color index buffers

**C SPECIFICATION**

```c
void glClearIndex( GLfloat c )
```

**PARAMETERS**

- `c`

Specifies the index used when the color index buffers are cleared. The default value is zero.

**DESCRIPTION**

`glClearIndex` specifies the index used by `glClear` to clear the color index buffers. `c` is not clamped.

Rather, `c` is converted to a fixed-point value with unspecified precision to the right of the binary point. The integer part of this value is then masked with $2^m - 1$, where `m` is the number of bits in a color index stored in the frame buffer.

**ERRORS**

- `GL_INVALID_OPERATION` is generated if `glClearIndex` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- glGet with argument `GL_INDEX_CLEAR_VALUE`
- glGet with argument `GL_INDEX_BITS`

SEE ALSO

- 'glClear''

**glClearStencil**
is the intersection of the defined half-spaces, it is always convex.

\( \text{glClipPlane} \) specifies a half-space using a four-component plane equation. When \( \text{glClipPlane} \) is called, equation is transformed by the inverse of the modelview matrix and stored in the resulting eye coordinates. Subsequent changes to the modelview matrix have no effect on the stored plane-equation components. If the dot product of the eye coordinates of a vertex with the stored plane equation components is positive or zero, the vertex is in with respect to that clipping plane. Otherwise, it is out.

### C SPECIFICATION

```c
void glClearStencil( GLint s )
```

#### PARAMETERS

- **s** Specifies the index used by \( \text{glClear} \) to clear the stencil buffer. The default value is zero.

#### DESCRIPTION

\( \text{glClearStencil} \) specifies the index used by \( \text{glClear} \) to clear the stencil buffer. \( s \) is masked with \( 2^m - 1 \), where \( m \) is the number of bits in the stencil buffer.

#### ERRORS

- **GL_INVALID_ENUM** is generated if \( \text{plane} \) is not an accepted value.
- **GL_INVALID_OPERATION** is generated if \( \text{glClearStencil} \) is called between a call to \( \text{glBegin} \) and the corresponding call to \( \text{glEnd} \).

#### ASSOCIATED GETS

- \( \text{glGet} \) with argument \( \text{GL_STENCIL_CLEAR_VALUE} \)
- \( \text{glGet} \) with argument \( \text{GL_STENCIL_BITS} \)

#### SEE ALSO

- "\( \text{glClear} \)"

### glColor

#### NAME

\( \text{glColor} \) — specify plane against which all geometry is clipped

#### C SPECIFICATION

```c
void glColor3b( GLbyte red, GLbyte green, GLbyte blue )
void glColor3d( GLdouble red, GLdouble green, GLdouble blue )
void glColor3f( GLfloat red, GLfloat green, GLfloat blue )
void glColor3i( GLint red, GLint green, GLint blue )
void glColor3s( GLshort red, GLshort green, GLshort blue )
void glColor3ub( GLubyte red, GLubyte green, GLubyte blue )
void glColor3ui( GLuint red, GLuint green, GLuint blue )
void glColor3us( GLushort red, GLushort green, GLushort blue )
void glColor4b( GLbyte red, GLbyte green, GLbyte blue, GLbyte alpha )
void glColor4d( GLdouble red, GLdouble green, GLdouble blue, GLdouble alpha )
void glColor4f( GLfloat red, GLfloat green, GLfloat blue, GLfloat alpha )
void glColor4i( GLint red, GLint green, GLint blue, GLint alpha )
void glColor4s( GLshort red, GLshort green, GLshort blue, GLshort alpha )
void glColor4ub( GLubyte red, GLubyte green, GLubyte blue, GLubyte alpha )
void glColor4ui( GLuint red, GLuint green, GLuint blue, GLuint alpha )
void glColor4us( GLushort red, GLushort green, GLushort blue, GLushort alpha )
```

Geometry is always clipped against the boundaries of a six-plane frustum in \( x, y, \) and \( z \). \( \text{glClipPlane} \) allows the specification of additional planes, not necessarily perpendicular to the \( x, y, \) or \( z \) axis, against which all geometry is clipped. Up to \( \text{GL_MAX_CLIP_PLANES} \) planes can be specified, where \( \text{GL_MAX_CLIP_PLANES} \) is at least six in all implementations. Because the resulting clipping region is the intersection of the defined half-spaces, it is always convex.

\( \text{glClipPlane} \) specifies a half-space using a four-component plane equation. When \( \text{glClipPlane} \) is called, equation is transformed by the inverse of the modelview matrix and stored in the resulting eye coordinates. Subsequent changes to the modelview matrix have no effect on the stored plane-equation components. If the dot product of the eye coordinates of a vertex with the stored plane equation components is positive or zero, the vertex is in with respect to that clipping plane. Otherwise, it is out.

Clipping planes are enabled and disabled with \( \text{glEnable} \) and \( \text{glDisable} \), and called with the argument \( \text{GL_CLIP_PLANE} i \), where \( i \) is the plane number.

```c
void glClearStencil( GLint s )
```

#### PARAMETERS

- **s** Specifies the index used when the stencil buffer is cleared. The default value is zero.

#### ASSOCIATED GETS

- \( \text{glGet} \) with argument \( \text{GL_STENCIL_CLEAR_VALUE} \)
- \( \text{glGet} \) with argument \( \text{GL_STENCIL_BITS} \)

#### SEE ALSO

- "\( \text{glClear} \)"
- "\( \text{glEnable} \)"

---

#### NAME

\( \text{glClearStencil} \) — specify value for the stencil buffer

#### C SPECIFICATION

```c
void glClearStencil( GLint s )
```

#### PARAMETERS

- **s** Specifies the index used when the stencil buffer is cleared. The default value is zero.

#### DESCRIPTION

\( \text{glClearStencil} \) specifies the index used by \( \text{glClear} \) to clear the stencil buffer. \( s \) is masked with \( 2^m - 1 \), where \( m \) is the number of bits in the stencil buffer.

#### ASSOCIATED GETS

- \( \text{glGet} \) with argument \( \text{GL_STENCIL_CLEAR_VALUE} \)
- \( \text{glGet} \) with argument \( \text{GL_STENCIL_BITS} \)

#### SEE ALSO

- "\( \text{glClear} \)"
The current color can be updated at any time. In particular, `glColor` can be called between a call to `glBegin` and the corresponding call to `glEnd`.

**Associated Gets**

- `glGet` with argument `GL_CURRENT_COLOR`
- `glGet` with argument `GL_RGBA_MODE`

**See Also**

- `glIndex`
**NAME**

**glCopyPixels** — copy pixels in the frame buffer

**C SPECIFICATION**

```c
void glCopyPixels( GLint x, GLint y, GLsizei width, GLsizei height, GLenum type );
```

**PARAMETERS**

- `x`, `y`: Specify the window coordinates of the lower left corner of the rectangular region of pixels to be copied. Both must be nonnegative.
- `width`, `height`: Specify the dimensions of the rectangular region of pixels to be copied. Both must be nonnegative.
- `type`: Specifies whether color values, depth values, or stencil values are to be copied. Symbolic constants `GL_COLOR`, `GL_DEPTH`, and `GL_STENCIL` are accepted.

**DESCRIPTION**

`glCopyPixels` copies a screen-aligned rectangle of pixels from the specified frame buffer location to a region relative to the current raster position. Its operation is well defined only if the entire pixel source region is within the exposed portion of the window. Results of copies from outside the window, or from regions of the window that are not exposed, are hardware dependent and undefined.

Several parameters control the processing of the pixel data while it is being copied. These parameters are set with three commands: `glPixelTransfer`, `glPixelMap`, and `glPixelZoom`. This reference page describes the effects of `glCopyPixels` of most, but not all, of the parameters specified by these three commands.

`glCopyPixels` copies values from each pixel with the lower left-hand corner at `(x + i, y + j)` for `0 ≤ i < width` and `0 ≤ j < height`. This pixel is said to be the `ith` pixel in the `jth` row. Pixels are copied in row order from the lowest to the highest row, left to right in each row.

**NOTES**

`glColorMaterial` allows a subset of material parameters to be changed for each vertex using only the `glMaterial` command, without calling `glMaterial`. If only such a subset of parameters is to be specified for each vertex, `glColorMaterial` is preferred over calling `glMaterial`.

**ERRORS**

- `GL_INVALID_ENUM` is generated if `face` or `mode` is not an accepted value.
- `GL_INVALID_OPERATION` is generated if `glColorMaterial` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glIsEnabled` with argument `GL_COLOR_MATERIAL`
- `glGet` with argument `GL_COLOR_MATERIAL_PARAMETER`
- `glGet` with argument `GL_COLOR_MATERIAL_FACE`

**SEE ALSO**

- `&1Color`, `&1Enable`, `&1Light`, `&1LightModel`, `&1Material`
GL_DEPTH

Depth values are read from the depth buffer and converted directly to an internal fixed-point format with unspecified precision. The resulting floating-point depth value is then multiplied by GL_DEPTH_SCALE and added to GL_DEPTH_BIAS. The result is clamped to the range [0,1].

GL_STENCIL

Stencil indices are read from the stencil buffer and converted to an internal fixed-point format with an unspecified number of bits to the right of the binary point. Each fixed-point index is then shifted left by GL_INDEX_SHIFT bits, and added to GL_INDEX_OFFSET. If GL_INDEX_SHIFT is negative, the shift is to the right. In either case, zero bits fill otherwise unspecified bit locations in the result. If GL_MAP_STENCIL is true, the index is replaced with the value that it references in lookup table GL PIXEL MAP S TO S. Whether the lookup replacement of the index is done or not, the integer part of the index is then ANDed with \(2^b - 1\), where \(b\) is the number of bits in the stencil buffer. The resulting stencil indices are then written to the stencil buffer such that the index read from the \(j\)th location of the \(j\)th row is written to location \(x + i, y + j\), where \((x, y)\) is the current raster position. Only the pixel ownership test, the scissor test, and the stencil write mask affect these writes.

The rasterization described thus far assumes pixel zoom factors of 1.0. If GLPixelZoom is used to change the \(x\) and \(y\) pixel zoom factors, pixels are converted to fragments as follows. If \((x, y)\) is the current raster position, and a given pixel is in the \(i\)th location in the \(j\)th row of the source pixel rectangle, then fragments are generated for pixels whose centers are in the rectangle with corners at \((x + zoom_i x, y + zoom_i y)\) and \((x + zoom_j y, y + zoom_j y + 1)\), where \(zoom_i\) is the value of GL_ZOOM_X and \(zoom_y\) is the value of GL_ZOOM_Y.

EXAMPLES

To copy the color pixel in the lower left corner of the window to the current raster position, use

```c
void glGet with argument GL_CURRENT RASTER POSITION
```

NOTES

Modes specified by glGetStore have no effect on the operation of glGet

ERRORS

GL_INVALID_ENUM is generated if type is not an accepted value.

GL_INVALID_VALUE is generated if either width or height is negative.

GL_INVALID_OPERATION is generated if type is GL_DEPTH and there is no depth buffer.

GL_INVALID_OPERATION is generated if type is GL_STENCIL and there is no stencil buffer.

GL_INVALID_OPERATION is generated if glCopyPixels is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

 NSLayoutConstraint

NAME

glCullFace -- specify whether front—or back-facing facets can be culled

C SPECIFICATION

void glGet with argument GL_CURRENT RASTER POSITION

PARAMETERS

- Specifies whether front—or back-facing facets are candidates for culling. Symbolic constants GL_FRONT and GL_BACK are accepted. The default value is GL_BACK.

DESCRIPTION

glCullFace specifies whether front—or back-facing facets are culled (as specified by mode) when facet culling is enabled. Facet culling is enabled and disabled using the glEnable and glDisable commands with the argument GL_CULL_FACE. Facets include triangles, quadrilaterals, polygons, and rectangles.

glFrontFace specifies which of the clockwise and counterclockwise facets are front-facing and back-facing. See "glFrontFace".

ERRORS

GL_INVALID_ENUM is generated if mode is not an accepted value.

GL_INVALID_OPERATION is generated if glCullFace is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

glIsEnabled with argument GL CULL FACE
**NAME**
gDeleteLists – delete a contiguous group of display lists

**C SPECIFICATION**

```c
void glDeleteLists( GLuint list, GLsizei range )
```

**PARAMETERS**

- `list` Specifies the integer name of the first display list to delete.
- `range` Specifies the number of display lists to delete.

**DESCRIPTION**

gDeleteLists causes a contiguous group of display lists to be deleted. `list` is the name of the first display list to be deleted, and `range` is the number of display lists to delete. All display lists with lists `d` at `list` + `range` – 1 are deleted.

All storage locations allocated to the specified display lists are freed, and the names are available for reuse at a later time. Names within the range that do not have an associated display list are ignored. If range is zero, nothing happens.

**ERRORS**

- `GL_INVALID_VALUE` is generated if `range` is negative.
- `GL_INVALID_OPERATION` is generated if `glDeleteLists` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**SEE ALSO**

- "glCallList", "glCallLists", "glGenLists", "glIsList", "glNewList"

---

**NAME**
gDepthFunc – specify the value used for depth buffer comparisons

**C SPECIFICATION**

```c
void glDepthFunc( GLenum func )
```

**PARAMETERS**

- `func` Specifies the depth comparison function. Symbolic constants are accepted. The default value is `GL_LESS`.

**DESCRIPTION**

gDepthFunc specifies the function used to compare each incoming pixel z value with the z value present in the depth buffer. The comparison is performed only if depth testing is enabled. (See "glEnable" and `glDisable of GL_DEPTH_TEST`.)

`func` specifies the conditions under which the pixel will be drawn. The comparison functions are as follows:

- `GL_NEVER` Never passes.
- `GL_LESS` Passes if the incoming z value is less than the stored z value.
- `GL_EQUAL` Passes if the incoming z value is equal to the stored z value.
- `GL_LEQUAL` Passes if the incoming z value is less than or equal to the stored z value.
- `GL_GREATER` Passes if the incoming z value is greater than the stored z value.
- `GL_NOTEQUAL` Passes if the incoming z value is not equal to the stored z value.
- `GL_GEQUAL` Passes if the incoming z value is greater than or equal to the stored z value.
- `GL_ALWAYS` Always passes.

The default value of `func` is `GL_LESS`. Initially, depth testing is disabled.

**ERRORS**

- `GL_INVALID_ENUM` is generated if `func` is not an accepted value.
- `GL_INVALID_OPERATION` is generated if `glDepthFunc` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

`glGet with argument GL_DEPTH_FUNC`

**SEE ALSO**

- "glDepthRange", "glEnable"

---

**NAME**
gDepthMask – enable or disable writing into the depth buffer

**C SPECIFICATION**

```c
void glDepthMask( GLboolean flag )
```

**PARAMETERS**

- `flag` Specifies whether the depth buffer is enabled for writing. If `flag` is zero, depth buffer writing is disabled. Otherwise, it is enabled. Initially, depth buffer writing is enabled.

**DESCRIPTION**

- `GL_ALWAYS` are accepted. The default value is `GL_LESS`.
**glDepthMask** specifies whether the depth buffer is enabled for writing. If flag is zero, depth buffer writing is disabled. Otherwise, it is enabled. Initially, depth buffer writing is enabled.

**ERRORS**

`GL_INVALID_OPERATION` is generated if `glDepthMask` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

`glGet` with argument `GL_DEPTH_WRITEMASK`.

**SEE ALSO**

"glColorMask", "glDepthFunc", "glDepthRange", "glIndexMask", "glStencilMask"

**glDepthRange**

**NAME**

`glDepthRange` — specify the mapping of z values from normalized device coordinates to window coordinates.

**C SPECIFICATION**

```c
void glDepthRange ( GLclampd near, GLclampd far )
```

**PARAMETERS**

- **near** Specifies the mapping of the near clipping plane to window coordinates. The default value is 0.
- **far** Specifies the mapping of the far clipping plane to window coordinates. The default value is 1.

**DESCRIPTION**

After clipping and division by w, z coordinates range from −1.0 to 1.0, corresponding to the near and far clipping planes. `glDepthRange` specifies a linear mapping of the normalized z coordinates in this range to window z coordinates. Regardless of the actual depth buffer implementation, window coordinate depth values are treated as though they range from 0.0 through 1.0 (like color components). Thus, the values accepted by `glDepthRange` are both clamped to this range before they are accepted. The default mapping of 0,1 maps the near plane to 0 and the far plane to 1. With this mapping, the depth buffer range is fully utilized.

**NOTES**

It is not necessary that near be less than far. Reverse mappings such as 1,0 are acceptable.

**ERRORS**

`GL_INVALID_OPERATION` is generated if `glDepthRange` is called between a call to `glBegin` and the corresponding call to `glEnd`.
GL_AUX Only auxiliary color buffer is written.
If more than one color buffer is selected for drawing, then blending or logical operations are computed and applied independently for each color buffer and can produce different results in each buffer.
Monoscopic contexts include only left buffers, and stereoscopic contexts include both left and right buffers. Likewise, single-buffered contexts include only front buffers, and double-buffered contexts include both front and back buffers. The context is selected at GL initialization.

NOTES
It is always the case that GL_AUX = GL_AUX0 + i.

ERRORS
GL_INVALID_ENUM is generated if mode is not an accepted value.
GL_INVALID_OPERATION is generated if glDrawBuffer is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
gGet with argument GL_DRAW_BUFFER
gGet with argument GL_AUX_BUFFERS

SEE ALSO
"glBlendFunc", "glColorMask", "glIndexMask", "glLogicOp", glReadSource

gDrawPixels
NAME
gDrawPixels — write a block of pixels to the frame buffer

C SPECIFICATION

void glDrawPixels(GLsizei width, GLsizei height, GLenum format, GLenum type, const GLvoid *pixels)

PARAMETERS
width, height Specify the dimensions of the pixel rectangle that will be written into the frame buffer.
format Specifies the format of the pixel data. Symbolic constants GL_COLOR_INDEX, GL_STENCIL_INDEX, GL_DEPTH_COMPONENT, GL_RGB, GL_RED, GL_GREEN, GL_BLUE, GL_ALPHA, GL_RGB, GL_INDEX, GL_LUMINANCE, and GL_LUMINANCE_ALPHA are accepted.
type Specifies the data type for pixels. Symbolic constants GL_UNSIGNED_BYTE, GL_BYTE, GL_BITMAP, GL_UNSIGNED_SHORT, GL_SHORT, GL_UNSIGNED_INT, GL_INT, and GL_FLOAT are accepted.
pixels Specifies a pointer to the pixel data.

DESCRIPTION
gDrawPixels reads pixel data from memory and writes it into the frame buffer relative to the current raster position. Use glRasterPos to set the current raster position, and use glGet with argument GL_CURRENT_RASTER_POSITION to query the raster position.

Several parameters define the encoding of pixel data in memory and control the processing of the pixel data before it is placed in the frame buffer. These parameters are set with four commands: glPixelStore, glPixelTransfer, glPixelMap, and glPixelZoom. This reference page describes the effects on glDrawPixels of many, but not all, of the parameters specified by these four commands.

Data is read from pixels as a sequence of signed or unsigned bytes, signed or unsigned shorts, signed or unsigned integers, or single-precision floating-point values, depending on type. Each of these bytes, shorts, integers, or floating-point values is interpreted as one color or depth component, or one index, depending on format. Indices are always treated individually. Color components are treated as groups of one, two, three, or four values, again based on type. Each unsigned byte is treated as eight 1-bit pixels, with bit ordering determined by GL_UNPACK_LSB_FIRST (see glPixelStore).

The width and height pixels are read from memory, starting at location pixels. By default, these pixels are taken from adjacent memory locations, except that after all width pixels are read, the read pointer is advanced to the next four-byte boundary. The four-byte row alignment is specified by glPixelStore with argument GL_UNPACK_ALIGNMENT, and it can be set to one, two, four, or eight bytes. Other pixel store parameters specify different read pointer advancements, both before the first pixel is read, and after all width pixels are read. Refer to the glPixelStore reference page for details on these options.

The width and height pixels that are read from memory are each operated on in the same way, based on the values of several parameters specified by glPixelTransfer and glPixelMap. The details of these operations, as well as the target buffer into which the pixels are drawn, are specific to the format of the pixels, as specified by format. format can assume one of eleven symbolic values:

GL_COLOR_INDEX
Each pixel is a single value, a color index. It is converted to fixed-point format, with an unspecified number of bits to the right of the binary point, regardless of the memory data type. Floating-point values convert to true fixed-point values. Signed and unsigned integer data is converted with all fraction bits set to zero. Bitmap data convert to either 0.0 or 1.0.

Each fixed-point index is then shifted left by GL_INDEX_SHIFT bits and added to GL_INDEX_OFFSET. If GL_INDEX_SHIFT is negative, the shift is to the right. In either case, zero bits fill otherwise unspecified bit locations in the result.

If the GL is in RGBA mode, the resulting index is converted to an RGBA pixel using the GL_PIXEL_MAP_I_TO_R, GL_PIXEL_MAP_I_TO_G, GL_PIXEL_MAP_I_TO_B, and GL_PIXEL_MAP_I_TO_A tables. If the GL is in color index mode, and if GL_MAP_COLOR is true, the index is replaced with the value that it references in lookup table GL_PIXEL_MAP_I_TO_I. Whether the lookup replacement of the index is done or not, the integer part of the index is then ANDed with $2^b - 1$, where $b$ is the number of bits in a color index buffer.

The resulting indices or RGBA colors are then converted to fragments by attaching the current raster position 2 coordinate and texture coordinates to each pixel, then assigning x and y window coordinates to the nth fragment such that

$$x_n = x \mod \text{width}$$

$$y_n = y \mod \text{width}$$
where \((x_r, y_r)\) is the current raster position. These pixel fragments are then treated just like the fragments generated by rasterizing points, lines, or polygons. Texture mapping, fog, and all the fragment operations are applied before the fragments are written to the frame buffer.

**GL_STENCIL_INDEX**

Each pixel is a single value, a stencil index. It is converted to fixed-point format, with an unspecified number of bits to the right of the binary point, regardless of the memory data type. Floating-point values convert to true fixed-point values. Signed and unsigned integer data is converted with all fraction bits set to zero. Bitmap data convert to either 0.0 or 1.0.

Each fixed-point index is then shifted left by \(GL\_INDEX\_SHIFT\) bits, and added to \(GL\_INDEX\_OFFSET\). If \(GL\_INDEX\_SHIFT\) is negative, the shift is to the right. In either case, zero bits fill otherwise unspecified bit locations in the result. If \(GL\_MAP\_STENCIL\) is true, the index is replaced with the value that it references in lookup table \(GL\_PIXEL\_MAP\_S\_TO\_S\). Whether the lookup replacement of the index is done or not, the integer part of the index is then ANDed with \(2^b - 1\), where \(b\) is the number of bits in the stencil buffer. The resulting stencil indices are then written to the stencil buffer such that the \(n\)th index is written to location \((x_r + n \mod width, y_r + \lfloor n/width \rfloor)\), where \((x_r, y_r)\) is the current raster position. Only the pixel ownership test, the scissor test, and the stencil writemask affect these writes.

**GL_DEPTH_COMPONENT**

Each pixel is a single–depth component. Floating–point data is converted directly to an internal floating–point format with unspecified precision. Signed integer data is mapped linearly to the internal floating–point format such that the most positive representable integer value maps to 1.0, and the most negative representable value maps to –1.0. Unsigned integer data is mapped similarly; the largest integer value maps to 1.0, and zero maps to 0.0. The resulting floating–point depth value is then multiplied by \(GL\_DEPTH\_SCALE\) and added to \(GL\_DEPTH\_BIAS\). The result is clamped to the range \([0,1]\). The resulting depth components are then converted to fragments by attaching the current raster position color or color index and texture coordinates to each pixel, then assigning \(x\) and \(y\) window coordinates to the \(n\)th fragment such that 

\[
x_n = x_r + n \mod width
\]
\[
y_n = y_r + \left\lfloor \frac{n}{width} \right\rfloor
\]

where \((x_r, y_r)\) is the current raster position. These pixel fragments are then treated just like the fragments generated by rasterizing points, lines, or polygons. Texture mapping, fog, and all the fragment operations are applied before the fragments are written to the frame buffer.

**GL_RGBA**

Each pixel is a four–component group: red first, followed by green, followed by blue, followed by alpha. Floating–point values are converted directly to an internal floating–point format with unspecified precision. Signed integer values are mapped linearly to the internal floating–point format such that the most positive representable integer value maps to 1.0, and the most negative representable value maps to –1.0. Unsigned integer data is mapped similarly; the largest integer value maps to 1.0, and zero maps to 0.0. The resulting floating–point color values are then multiplied by \(GL\_c\_SCALE\) and added to \(GL\_c\_BIAS\). Where \(c\) is \(RED\), \(GREEN\), \(BLUE\), or \(ALPHA\) for the respective color components. The results are clamped to the range \([0,1]\).

The resulting RGBA colors are then converted to fragments by attaching the current raster position \(z\) coordinate and texture coordinates to each pixel, then assigning \(x\) and \(y\) window coordinates to the \(n\)th fragment such that

\[
x_n = x_r + n \mod width
\]
\[
y_n = y_r + \left\lfloor \frac{n}{width} \right\rfloor
\]

where \((x_r, y_r)\) is the current raster position. These pixel fragments are then treated just like the fragments generated by rasterizing points, lines, or polygons. Texture mapping, fog, and all the fragment operations are applied before the fragments are written to the frame buffer.
the corresponding call to glEnd.

ASSOCIATED GETS

**glGet** with argument **GL_CURRENT_RASTER_POSITION**

**glGet** with argument **GL_CURRENT_RASTER_POSITION_VALID**

SEE ALSO

"glAlphaFunc", "glBlendFunc", "glCopyPixels", "glDepthFunc", "glLogicOp", "glPixelMap", "glPixelStore", "glPixelTransfer", "glPixelZoom", "glRasterPos", "glReadPixels", "glScissor", "glStencilFunc"

**glEdgeFlag**

NAME

**glEdgeFlag**, **glEdgeFlagv** — flag edges as either boundary or nonboundary

C SPECIFICATION

```c
void glEdgeFlag( GLboolean flag )
```

PARAMETERS

- `flag`: Specifies the current edge flag value, either true or false.

C SPECIFICATION

```c
void glEdgeFlagv( const GLboolean *flag )
```

PARAMETERS

- `flag`: Specifies a pointer to an array that contains a single Boolean element, which replaces the current edge flag value.

DESCRIPTION

Each vertex of a polygon, separate triangle, or separate quadrilateral specified between a ``` glBegin ``` / ``` glEnd ``` pair is marked as the start of either a boundary or nonboundary edge. If the current edge flag is true when the vertex is specified, the vertex is marked as the start of a boundary edge. Otherwise, the vertex is marked as the start of a nonboundary edge. **glEdgeFlag** sets the edge flag to true if ``` flag ``` is nonzero, false otherwise.

The vertices of connected triangles and connected quadrilaterals are always marked as boundary, regardless of the value of the edge flag. Boundary and nonboundary edge flags on vertices are significant only if **GL_POLYGON_MODE** is set to **GL_POINT** or **GL_LINE**. See **"glPolygonMode"**.

Initially, the edge flag bit is true.

NOTES

The current edge flag can be updated at any time. In particular, **glEdgeFlag** can be called between a call to **glBegin** and the corresponding call to **glEnd**.

The following table summarizes the meaning of the valid constants for the `type` parameter:

<table>
<thead>
<tr>
<th><code>type</code></th>
<th><code>corresponding type</code></th>
</tr>
</thead>
<tbody>
<tr>
<td>GL_UNSIGNED_BYTE</td>
<td>unsigned 8-bit integer</td>
</tr>
<tr>
<td>GL_BYTE</td>
<td>signed 8-bit integer</td>
</tr>
<tr>
<td>GL_BITMAP</td>
<td>single bits in unsigned 8-bit integers</td>
</tr>
<tr>
<td>GL_UNSIGNED_SHORT</td>
<td>signed 16-bit integer</td>
</tr>
<tr>
<td>GL_SHORT</td>
<td>signed 16-bit integer</td>
</tr>
<tr>
<td>GL_UNSIGNED_INT</td>
<td>unsigned 32-bit integer</td>
</tr>
<tr>
<td>GL_INT</td>
<td>32-bit integer</td>
</tr>
<tr>
<td>GL_FLOAT</td>
<td>single-precision floating-point</td>
</tr>
</tbody>
</table>

The rasterization described thus far assumes pixel zoom factors of 1.0. If **glPixelZoom** is used to change the x and y pixel zoom factors, pixels are converted to fragments as follows. If (x, y) is the current raster position, and a given pixel is in the nth column and mth row of the pixel rectangle, then fragments are generated for pixels whose centers are in the rectangle with corners at:

\[(x + zoom_x \cdot n, y + zoom_y \cdot m) \],

\[(x + zoom_x \cdot (n + 1), y + zoom_y \cdot (m + 1))\]

where `zoom_x` is the value of **GL_ZOOM_X** and `zoom_y` is the value of **GL_ZOOM_Y**.

ERRORS

**GL_INVALID_VALUE** is generated if either width or height is negative.

**GL_INVALID_ENUM** is generated if `format` or `type` is not one of the accepted values.

**GL_INVALID_OPERATION** is generated if `format` is **GL_RED**, **GL_GREEN**, **GL_BLUE**, **GL_ALPHA**, **GL_RGB**, **GL_RGBA**, **GL_LUMINANCE**, **GL_LUMINANCE_ALPHA**, and the `GL` is in color index mode.

**GL_INVALID_ENUM** is generated if `type` is **GL_BITMAP** and `format` is **GL_RGB**, **GL_RGBA**, **GL_LUMINANCE**, or **GL_LUMINANCE_ALPHA**, and the `GL` is in color index mode.

**GL_INVALID_OPERATION** is generated if `format` is **GL_STENCIL_INDEX** and there is no stencil buffer.

**GL_INVALID_OPERATION** is generated if **glDrawPixels** is called between a call to **glBegin** and the corresponding call to **glEnd**.
ASSOCIATED GETS

GL_DITHER
- If enabled, dither color components or indices before they are written to the color buffer.

GL_FOG
- If enabled, blend a fog color into the posttexturing color. See "glFog".

GL_LIGHT
- If enabled, include light in the evaluation of the lighting equation. See "glLightModel" and "glLight".

GL_LIGHTING
- If enabled, use the current lighting parameters to compute the vertex color or index. Otherwise, simply associate the current color or index with each vertex. See "glLightModel", "glLightModel", and "glLight".

ASSOCIATED GETS

GL_LIGHTING
- If enabled, use the current lighting parameters to compute the vertex color or index. Otherwise, simply associate the current color or index with each vertex. See "glLightModel", "glLightModel", and "glLight".

GL_LINE_SMOOTH
- If enabled, draw lines with correct filtering. Otherwise, draw aliased lines. See "glLineWidth".

GL_LINE_STIPPLE
- If enabled, use the current line stipple pattern when drawing lines. See "glLineStipple".

GL_LOGIC_OP
- If enabled, apply the currently selected logical operation to the incoming and colorbuffer indices. See "glLogicOp".

GL_MAP1_COLOR_4
- If enabled, calls to glEvalCoord1, glEvalMesh1, and glEvalPoint1 will generate RGBA values. See "glMap1".

GL_MAP1_INDEX
- If enabled, calls to glEvalCoord1, glEvalMesh1, and glEvalPoint1 will generate color indices. See "glMap1".

GL_MAP1_NORMAL
- If enabled, calls to glEvalCoord1, glEvalMesh1, and glEvalPoint1 will generate normals. See "glMap1".

GL_MAP2_COLOR_4
- If enabled, calls to glEvalCoord2, glEvalMesh2, and glEvalPoint2 will generate RGBA values. See "glMap2".

GL_MAP2_INDEX
- If enabled, calls to glEvalCoord2, glEvalMesh2, and glEvalPoint2 will generate color indices. See "glMap2".

GL_MAP2_NORMAL
- If enabled, calls to glEvalCoord2, glEvalMesh2, and glEvalPoint2 will generate normals. See "glMap2".

C SPECIFICATION

void glEnable ( GLenum cap )

PARAMETERS
- cap: Specifies a symbolic constant indicating a GL capability.

void glDisable ( GLenum cap )

PARAMETERS
- cap: Specifies a symbolic constant indicating a GL capability.

DESCRIPTION

- glEnable and glDisable enable and disable various capabilities. Use glEnable or glGet to determine the current setting of any capability.

- Both glEnable and glDisable take a single argument, cap, which can assume one of the following values:

  GL_ALPHA_TEST
  - If enabled, do alpha testing. See "glAlphaFunc".

  GL_AUTO_NORMAL
  - If enabled, compute surface normal vectors analytically when either GL_MAP2_VERTEX_3 or GL_MAP2_VERTEX_4 is used to generate vertices. See "glMap2".

  GL_BLEND
  - If enabled, blend the incoming RGBA color values with the values in the color buffers. See "glBlendFunc".

  GL_CLIP_PLANE
  - If enabled, clip geometry against user-defined clipping planes. See "glClipPlane".

  GL_COLOR_MATERIAL
  - If enabled, have one or more material parameters track the current color. See "glColorMaterial".

  GL_CULL_FACE
  - If enabled, cull polygons based on their winding in window coordinates. See "glCullFace".

  GL_DEPTH_TEST
  - If enabled, do depth comparisons and update the depth buffer. See "glDepthFunc"
If enabled, calls to 

```plaintext
.glEvalCoord2, .glEvalMesh2, and .glEvalPoint2
```

will generate texture coordinates. See 

```plaintext
.glMap2
```

ERRORS

```plaintext
GL_INVALID_ENUM is generated if glCap is not one of the values listed above.
GL_INVALID_OPERATION is generated if glEnable is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO


.glEvalCoord

NAME

```plaintext
glEvalCoord1d, glEvalCoord1f, glEvalCoord2d, glEvalCoord2f, glEvalCoord1dv, glEvalCoord1fv, glEvalCoord2dv, glEvalCoord2fv — evaluate enabled one- and two-dimensional maps.
```

C SPECIFICATION

```plaintext
void glEvalCoord1d ( GLdouble u)
void glEvalCoord1f ( GLfloat u)
void glEvalCoord2d ( GLdouble u, GLdouble v)
void glEvalCoord2f ( GLfloat u, GLfloat v)
```

PARAMETERS

```plaintext
u Specifies a value that is the domain coordinate u to the basis function defined in a previous glMap1 or glMap2 command.
v Specifies a value that is the domain coordinate v to the basis function defined in a previous glMap2 command. This argument is not present in an glEvalCoord1 command.
```

C SPECIFICATION

```plaintext
void glEvalCoord1d ( const GLdouble *u)
void glEvalCoord1f ( const GLfloat *u)
void glEvalCoord2d ( const GLdouble *u, const GLdouble *v)
void glEvalCoord2f ( const GLfloat *u, const GLfloat *v)
```

PARAMETERS

```plaintext
u Specifies a pointer to an array containing either one or two domain coordinates. The first coordinate is u. The second coordinate is v, which is present only in glEvalCoord2 versions.
```
DESCRIPTION

gEvalCoord1 evaluates enabled one-dimensional maps at argument u.  gEvalCoord2 does the same for two-dimensional maps using two domain values, u and v.  Maps are enabled with gEnable and gMap2 and enabled and disabled with gEnable and gDisable.

When one of the gEvalCoord commands is issued, all currently enabled maps of the indicated dimension are evaluated. Then, for each enabled map, it is as if the corresponding GL command was issued with the computed value. That is, if GL_MAP1_INDEX or GL_MAP2_INDEX is enabled, a glIndex command is simulated. If GL_MAP1_COLOR_4 or GL_MAP2_COLOR_4 is enabled, a gColor command is simulated. If GL_MAP1_INDEX or GL_MAP2_INDEX is enabled, a normal vector is produced, and if any of GL_MAP1_TEXTURE_COORD_1, GL_MAP2_TEXTURE_COORD_2, GL_MAP2_TEXTURE_COORD_3, or GL_MAP2_TEXTURE_COORD_4 is enabled, then an appropriate glTexCoord command is simulated.

The GL uses evaluated values instead of current values for those evaluations that are enabled, and current values otherwise, for color, color index, normal, and texture coordinates. However, the evaluated values do not update the current values. Thus, if glVertex commands are interspersed with gEvalCoord commands, the color, normal, and texture coordinates associated with the glVertex commands are not affected by the values generated by the gEvalCoord commands, but rather only by the most recent gColor, glIndex, gNormal, and glTexCoord commands.

No commands are issued for maps that are not enabled. If more than one texture evaluation is enabled for a particular dimension (for example, GL_MAP2_TEXTURE_COORD_1 and GL_MAP2_TEXTURE_COORD_2), then only the evaluation of the map that produces the larger number of coordinates (in this case, GL_MAP2_TEXTURE_COORD_2) is carried out.

If automatic normal generation is enabled, by calling gEnable with argument GL_AUTO_NORMAL, gEvalCoord2 generates surface normals analytically, regardless of the contents or enabling of the GL_MAP2_NORMAL map. Let

\[
m = \frac{\partial p}{\partial u} \times \frac{\partial p}{\partial v}
\]

Then the generated normal \( n \) is

\[
n = \frac{m}{|m|}
\]

If automatic normal generation is disabled, the corresponding normal map GL_MAP2_NORMAL, if enabled, is used to produce a normal. If neither automatic normal generation nor a normal map is enabled, no normal is generated for gEvalCoord2 commands.

ASSOCIATED GETS

gIsEnabled with argument GL_MAP1_VERTEX_3

gIsEnabled with argument GL_MAP1_VERTEX_4

gIsEnabled with argument GL_MAP1_INDEX

gIsEnabled with argument GL_MAP1_COLOR_4

gIsEnabled with argument GL_MAP1_NORMAL

gIsEnabled with argument GL_MAP1_TEXTURE_COORD_1

gIsEnabled with argument GL_MAP1_TEXTURE_COORD_2

gIsEnabled with argument GL_MAP1_TEXTURE_COORD_3

gIsEnabled with argument GL_MAP1_TEXTURE_COORD_4

gIsEnabled with argument GL_MAP2_VERTEX_3

gIsEnabled with argument GL_MAP2_VERTEX_4

gIsEnabled with argument GL_MAP2_INDEX

gIsEnabled with argument GL_MAP2_COLOR_4

gIsEnabled with argument GL_MAP2_NORMAL

gIsEnabled with argument GL_MAP2_TEXTURE_COORD_1

gIsEnabled with argument GL_MAP2_TEXTURE_COORD_2

gIsEnabled with argument GL_MAP2_TEXTURE_COORD_3

gIsEnabled with argument GL_MAP2_TEXTURE_COORD_4

gIsEnabled with argument GL_AUTO_NORMAL

gGetMap

SEE ALSO

"glBegin", "gColor", "gEnable", "gEvalMesh", "gEvalCoord", "glIndex", "glMap1", "glMap2", "gMapGrid", "gNormal", "glTexCoord", "glVertex"

NAME

gEvalMesh1, gEvalMesh2 — compute a one- or two-dimensional grid of points or lines

C SPECIFICATION

void gEvalMesh1 (GLenum mode, GLint i1, GLint i2)

PARAMETERS

mode In gEvalMesh1, specifies whether to compute a one-dimensional mesh of points or lines. Symbolic constants GL_POINT and GL_LINE are accepted. i1, i2 Specify the first and last integer values for grid domain variable.

C SPECIFICATION

void gEvalMesh2 (GLenum mode, GLint i1, GLint j1, GLint i2, GLint j2)

PARAMETERS

mode In gEvalMesh2, specifies whether to compute a two-dimensional mesh of points, lines, or polygons. Symbolic constants GL_POINT, GL_LINE, and GL_FILL are
And finally, if the mode is GL_POINT, then a call to glEvalMesh2 is equivalent to:

```c
void glEvalPoint1(GLint i)
void glEvalPoint2(GLint i, GLint j)
```

**PARAMETERS**
- `i`: Specifies the integer value for grid domain variable.
- `j`: Specifies the integer value for grid domain variable (glEvalPoint2 only).

**DESCRIPTION**

glMapGrid and glEvalMesh are used in tandem to efficiently generate and evaluate a series of evenly spaced map domain values. glEvalMesh steps through the integer domain of a one- or two-dimensional grid, whose range is the domain of the evaluation maps specified by glMap1 and glMap2. glMap1 and glMap2 are used in tandem to efficiently evaluate a series of evenly spaced map domain values. Calling glEvalPoint1 is equivalent to calling glEvalCoord1(i · Δu + u1);

where

```plaintext
Δu = (u2 − u1) / n
Δv = (v2 − v1) / m,
```

and `n`, `u1`, and `u2` are the arguments to the most recent glMapGrid1 command. `type` is GL_POINTS if the mode is GL_POINT, or GL_LINES if the mode is GL_LINE. The one absolute numeric requirement is that if `i = n`, then the value computed from `i · Δu + u1` is exactly `u2`.

In the two-dimensional case, glEvalMesh2 lets

```plaintext
Δu = (u2 − u1) / n
Δv = (v2 − v1) / m,
```

where `n`, `u1`, `u2`, `m`, `v1`, and `v2` are the arguments to the most recent glMapGrid2 command. Then, if the mode is GL_FILL, the glEvalMesh2 command is equivalent to:

```c
void glEvalCoord1(GLint i)
void glEvalCoord2(GLint i, GLint j)
```

for `j = j1; j <= j2; j += 1`

```c
void glBegin(GL_QUAD_STRIP);
  for (i = i1; i <= i2; i += 1) {
    glEvalCoord2((i − i1) · Δu + u1, j · Δv + v1);
  }
  glEnd();
```

If the mode is GL_LINE, then a call to glEvalMesh2 is equivalent to:

```c
void glBegin(GL_LINE_STRIP);
  for (i = i1; i <= i2; i += 1) {
    glEvalCoord2((i − i1) · Δu + u1, j · Δv + v1);
  }
  glEnd();
```

for `j = j1; j <= j2; j += 1`

```c
void glBegin(GL_LINE_STRIP);
  for (i = i1; i <= i2; i += 1) {
    glEvalCoord2((i − i1) · Δu + u1, (j + 1) · Δv + v1);
  }
  glEnd();
```

In all three cases, the only absolute numeric requirements are that if `i = n`, then the value computed from `i · Δu + u1` is exactly `u2`, and if `j = m`, then the value computed from `j · Δv + v1` is exactly `v2`.

**ERRORS**

GL_INVALID_ENUM is generated if `mode` is not an accepted value.

GL_INVALID_OPERATION is generated if glEvalMesh is called between a call to glBegin and the corresponding call to glEnd.

**ASSOCIATED GETS**

glGet with argument GL_MAP1_GRID_DOMAIN
- glGet with argument GL_MAP2_GRID_DOMAIN
- glGet with argument GL_MAP1_GRID_SEGMENTS
- glGet with argument GL_MAP2_GRID_SEGMENTS

**SEE ALSO**

`glBegin`, `glEvalCoord`, `glEvalPoint`, `glMap1`, `glMap2`, `glMapGrid`
The feedback mode is enabled by calling `glRenderMode` with argument `GL_FEEDBACK`. Setting `GL_FEEDBACK` without establishing the feedback buffer, or calling `glFeedbackBuffer` while the GL is in feedback mode, is an error.

The GL is taken out of feedback mode by calling `glRenderMode` with a parameter value other than `GL_FEEDBACK`. When this is done while the GL is in feedback mode, `glRenderMode` returns the number of entries placed in the feedback array. The returned value never exceeds size. If the feedback data required more room than was available in buffer, `glFeedbackBuffer` returns a negative value.

While in feedback mode, each primitive that would be rasterized generates a block of values that get copied into the feedback array. If doing so would cause the number of entries to exceed the maximum, the block is partially written so as to fill the array (if there is any room left at all), and an overflow flag is set. Each block begins with a code indicating the primitive type, followed by values that describe the primitive's vertices and associated data. Entries are also written for bitmaps and pixel rectangles. Feedback occurs after polygon culling and `glPolyMode` interpretation of polygons has taken place, so polygons that are culled are not returned in the feedback buffer. It can also occur after polygons with more than three edges are broken up into triangles, if the GL implementation renders polygons by performing this decomposition.

The `glPassThrough` command can be used to insert a marker into the feedback buffer. See `glPassThrough`.

Following is the grammar for the blocks of values written into the feedback buffer. Each primitive is indicated with a unique identifying value followed by some number of vertices. Polygon entries include an integer value indicating how many vertices follow. A vertex is fed back as some number of floating-point values, as determined by type. Colors are fed back as four values in RGBA mode and one value in color index mode.

```
feedbackList <- feedbackItem feedbackList | feedbackItem
feedbackItem <- point | lineSegment | polygon | bitmap | pixelRectangle | passThru
point <- GL_POINT_TOKEN vertex
lineSegment <- GL_LINE_TOKEN vertex vertex | GL_LINE_RESET_TOKEN vertex vertex
polygon <- GL_POLYGON_TOKEN n polySpec
polySpec <- polySpec vertex | vertex vertex vertex
bitmap <- GL_BITMAP_TOKEN vertex pixelRectangle
pixelRectangle <- GL_DRAW_PIXEL_TOKEN vertex | GL_COPY_PIXEL_TOKEN vertex
passThru <- GL_PASS_THROUGH_TOKEN value vertex vertex <- 2d | 3d | 3dColor | 3dColorTexture | 4dColorTexture
2d <- value value
3d <- value value value
3dColor <- value value value color
3dColorTexture <- value value value color tex
4dColorTexture <- value value value value tex
color <- rgba | index
rgba <- value value value
index <- value
tex <- value value value

ASSOCIATED GETS

glGet with argument GL_MAP1_GRID_DOMAIN
.glGet with argument GL_MAP2_GRID_DOMAIN
.glGet with argument GL_MAP1_GRID_SEGMENTS
.glGet with argument GL_MAP2_GRID_SEGMENTS

C SPECIFICATION

void glFeedbackBuffer(GLsizei size, GLenum type, GLvoid *buffer)

PARAMETERS

size Specifies the maximum number of values that can be written into buffer.
type Specifies a symbolic constant that describes the information that will be returned for each vertex. `GL_2D`, `GL_3D`, `GL_3D_COLOR`, `GL_3D_COLOR_TEXTURE`, and `GL_4D_COLOR_TEXTURE` are accepted.
buffer Returns the feedback data.

DESCRIPTION

The `glFeedbackBuffer` function controls feedback. Feedback, like selection, is a GL mode. The mode is selected by calling `glRenderMode` with `GL_FEEDBACK`. When the GL is in feedback mode, no pixels are produced by rasterization. Instead, information about primitives that would have been rasterized is fed back to the application using the GL.

`glFeedbackBuffer` has three arguments: `buffer` is a pointer to an array of floating-point values into which feedback information is placed. `size` indicates the size of the array. `type` is a symbolic constant describing the information that is fed back for each vertex. `glFeedbackBuffer` must be issued before

\[
\Delta u = \frac{(u_2 - u_1)}{n}
\]

and \(n\), \(u_1\), and \(u_2\) are the arguments to the most recent `glMap1` command. The one absolute numeric requirement is that if \(i = n\), then the value computed from \(i \cdot \Delta u + u_1\) is exactly \(u_2\).

In the two-dimensional case, `glEvalPoint2` let

\[
\Delta v = \frac{(v_2 - v_1)}{m}
\]

where \(u_1, u_2, m, v_1, \) and \(v_2\) are the arguments to the most recent `glMap1` command. Then the `glEvalPoint2` command is equivalent to calling

`glMapGrid1` command. The one absolute numeric requirement is that if \(i = n\), then the value computed from \(i \cdot \Delta v + v_1\) is exactly \(v_2\), and if \(j = m\), then the value computed from \(j \cdot \Delta v + v_1\) is exactly \(v_2\).

ASSOCIATED GETS

`glGet with argument GL_MAP1_GRID_DOMAIN`
`glGet with argument GL_MAP2_GRID_DOMAIN`
`glGet with argument GL_MAP1_GRID_SEGMENTS`
`glGet with argument GL_MAP2_GRID_SEGMENTS`

SEE ALSO

`glEvalCoord", "glEvalMesh", "glMap1", "glMap2", "glMapGrid"

glFeedbackBuffer

NAME

`glFeedbackBuffer` - controls feedback mode

The only absolute numeric requirements are that if \(i = n\), then the value computed from \(i \cdot \Delta u + u_1\) is exactly \(u_2\), and if \(j = m\), then the value computed from \(j \cdot \Delta v + v_1\) is exactly \(v_2\).
Feedback vertex coordinates are in window coordinates, except \( w \), which is in clip coordinates. Feedback colors are lighted, if lighting is enabled. Feedback texture coordinates are generated, if texture coordinate generation is enabled. They are always transformed by the texture matrix.

**NOTES**

`glFeedbackBuffer`, when used in a display list, is not compiled into the display list but rather is executed immediately.

**ERRORS**

- `GL_INVALID_ENUM` is generated if `type` is not an accepted value.
- `GL_INVALID_VALUE` is generated if `size` is negative.
- `GL_INVALID_OPERATION` is generated if `glFeedbackBuffer` is called while the render mode is `GL_FEEDBACK` or if `glRenderMode` is called with argument `GL_FEEDBACK` before `glFeedbackBuffer` is called at least once.
- `GL_INVALID_OPERATION` is generated if `glFeedbackBuffer` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**SEE ALSO**

`"glFlush", "glXWaitGL", "glXWaitX"`
ERRORS

GL_INVALID_OPERATION is generated if glFlush is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO

‘glFinish’

NAME

glFog

C SPECIFICATION

void glFog( GLenum pname, GLfloat param )
void glFogi( GLenum pname, GLint param )

PARAMETERS

pname Specifies a single−valued fog parameter. GL_FOG_MODE, GL_FOG_DENSITY, GL_FOG_START, GL_FOG_END, and GL_FOG_INDEX are accepted.

param Specifies the value that pname will be set to.

C SPECIFICATION

void glFogfv( GLenum pname, const GLfloat *params )
void glFogiv( GLenum pname, const GLint *params )

PARAMETERS

pname Specifies a fog parameter. GL_FOG_MODE, GL_FOG_DENSITY, GL_FOG_START, GL_FOG_END, GL_FOG_INDEX, and GL_FOG_COLOR are accepted.

params Specifies the value or values to be assigned to pname. GL_FOG_COLOR requires an array of four values. All other parameters accept an array containing only a single value.

DESCRIPTION

Fog is enabled and disabled with glEnable and glDisable using the argument GL_FOG. While enabled, fog affects rasterized geometry, bitmaps, and pixel blocks, but not buffer clear operations. glFog assigns the value or values in params to the fog parameter specified by pname. The accepted values for pname are as follows:

GL_FOG_MODE

params is a single integer or floating−point value that specifies the equation to be used to compute the fog blend factor, f. Three symbolic constants are accepted: GL_LINEAR, GL_EXP, and GL_EXP2. The equations corresponding to these symbolic constants are defined below. The default fog mode is GL_EXP.

GL_FOG_DENSITY

params is a single integer or floating−point value that specifies density, the fog density used in both exponential fog equations. Only nonnegative densities are accepted. fog density is the implementation−dependent maximum value such that the corresponding value of fog density is not representable.

glFogf, glFogi, glFogfv, glFogiv – specify fog parameters

GL_FOG_START

params is a single integer or floating−point value that specifies start, the near distance used in the linear fog equation. The default near distance is 0.0.

GL_FOG_END

params is a single integer or floating−point value that specifies end, the far distance used in the linear fog equation. The default far distance is 1.0.

GL_FOG_INDEX

params is a single integer or floating−point value that specifies if, the fog color index. The default fog index is 0.0.

GL_FOG_COLOR

params contains four integer or floating−point values that specify f_c, the fog color. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to −1.0. Floating−point values are mapped directly. After conversion, all color components are clamped to the range [0,1]. The default fog color is (0,0,0,0).

Fog blends a fog color with each rasterized pixel fragment’s posttexturing color using a blending factor f. Factor f is computed in one of three ways, depending on the fog mode. Let z be the distance in eye coordinates from the origin to the fragment being fogged. The equation for GL_LINEAR fog is

\[ f = \frac{\text{end} - z}{\text{end} - \text{start}} \]

The equation for GL_EXP fog is

\[ f = e^{(-\text{density} \cdot z)} \]

The equation for GL_EXP2 fog is

\[ f = e^{(-\text{density} \cdot z)^2} \]

Regardless of the fog mode, f is clamped to the range [0,1] after it is computed. Then, if the GL is in RGBA color mode, the fragment’s color C is replaced by

C' = C + (1 − f)C

In color index mode, the fragment’s color index i is replaced by

i' = i + (1 − f)i
ERRORS

GL_INVALID_ENUM is generated if pname is not an accepted value, or if pname is GL_FOG_MODE and params is not an accepted value.

GL_INVALID_VALUE is generated if pname is GL_FOG_DENSITY and params is negative.

GL_INVALID_OPERATION is generated if glFog is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
gIsEnabled with argument GL_FOG
gGet with argument GL_FOG_COLOR
gGet with argument GL_FOG_INDEX
gGet with argument GL_FOG_DENSITY
gGet with argument GL_FOG_START
gGet with argument GL_FOG_END
gGet with argument GL_FOG_MODE

SEE ALSO

‘glEnable’

### NAME

`glFrontFace` – define front– and back–facing polygons

### C SPECIFICATION

```c
void glFrontFace (GLenum mode)
```

### PARAMETERS

- **mode**
  Specifies the orientation of front–facing polygons. GL_CW and GL_CCW are accepted. The default value is GL_CCW.

### DESCRIPTION

In a scene composed entirely of opaque closed surfaces, back–facing polygons are never visible. Eliminating these invisible polygons has the obvious benefit of speeding up the rendering of the image. Elimination of back–facing polygons is enabled and disabled with `glEnable` and `glDisable` using argument GL_CULL_FACE.

The projection of a polygon to window coordinates is said to have clockwise winding if an imaginary object following the path from its first vertex, its second vertex, and so on, to its last vertex, and finally back to its first vertex, moves in a clockwise direction about the interior of the polygon. The polygon’s winding is said to be counterclockwise if the imaginary object following the same path moves in a counterclockwise direction about the interior of the polygon. `glFrontFace` specifies whether polygons with clockwise winding in window coordinates, or counterclockwise winding in window coordinates, are taken to be front–facing. Passing GL_CCW to mode selects counterclockwise polygons as front–facing. GL_CW selects clockwise polygons as front–facing. By default, counterclockwise polygons are taken to be front–facing.

ERRORS

GL_INVALID_ENUM is generated if mode is not an accepted value.

GL_INVALID_OPERATION is generated if `glFrontFace` is called between a call to `glBegin` and the corresponding call to `glEnd`.

ASSOCIATED GETS
gGet with argument GL_FRONT_FACE

SEE ALSO

‘glCullFace’, ‘glLightModel’

### NAME

`glFrustum` – multiply the current matrix by a perspective matrix

### C SPECIFICATION

```c
void glFrustum (GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble near, GLdouble far)
```

### PARAMETERS

- **left**, **right**, **bottom**, **top**, **near**, **far**
  Specify the coordinates for the left and right vertical clipping planes, the bottom and top horizontal clipping planes, the distances to the near and far depth clipping planes. Both distances must be positive.

### DESCRIPTION

`glFrustum` describes a perspective matrix that produces a perspective projection. (left, bottom, −near) and (right, top, −near) specify the points on the near clipping plane that are mapped to the lower left and upper right corners of the window, respectively, assuming that the eye is located at (0, 0, 0). −far specifies the location of the far clipping plane. Both near and far must be positive. The corresponding matrix is
The current matrix is multiplied by this matrix with the result replacing the current matrix. That is, if 
$M$ is the current matrix and $F$ is the frustum perspective matrix, then $M$ is replaced with $M \times F$. 

\[
\begin{pmatrix}
2\text{near} & 0 & A & 0 \\
\text{right - left} & 0 & 2\text{near} & B \\
\text{top - bottom} & 0 & 0 & C \\
0 & 0 & 0 & D \\
0 & 0 & -1 & 0
\end{pmatrix}
\]

\[A = \frac{\text{right} + \text{left}}{\text{right} - \text{left}}\]

\[B = \frac{\text{top} + \text{bottom}}{\text{top} - \text{bottom}}\]

\[C = -\frac{\text{far} + \text{near}}{\text{far} - \text{near}}\]

\[D = -\frac{2\text{far} \text{near}}{\text{far} - \text{near}}\]

The current matrix is multiplied by this matrix with the result replacing the current matrix. That is, if 
$M$ is the current matrix and $F$ is the frustum perspective matrix, then $M$ is replaced with $M \times F$. 
Use $\text{glPushMatrix}$ and $\text{glPopMatrix}$ to save and restore the current matrix stack.

NOTES
Depth buffer precision is affected by the values specified for near and far. The greater the ratio of far to 
near is, the less effective the depth buffer will be at distinguishing between surfaces that are near each 
other. If

roughly $\log_2 r$ bits of depth buffer precision are lost. Because $r$ approaches infinity as near approaches
zero, near must never be set to zero.

ERRORS
$\text{GL_INVALID_VALUE}$ is generated if near or far is not positive.

$\text{GL_INVALID_OPERATION}$ is generated if $\text{glFrustum}$ is called between a call to $\text{glBegin}$ and the 
corresponding call to $\text{glEnd}$.

ASSOCIATED GETS
$\text{glGet}$ with argument $\text{GL_MATRIX_MODE}$
$\text{glGet}$ with argument $\text{GL_MODELVIEW_MATRIX}$
$\text{glGet}$ with argument $\text{GL_PROJECTION_MATRIX}$
$\text{glGet}$ with argument $\text{GL_TEXTURE_MATRIX}$

SEE ALSO
"glOrtho", "glMatrixMode", "glMultMatrix", "glPushMatrix", "glViewport"

$\text{glGenLists}$

NAME
$\text{glGenLists}$ – generate a contiguous set of empty display lists

C SPECIFICATION
$\text{GLuint glGenLists}(\text{GLsizei range})$

PARAMETERS
range Specifies the number of contiguous empty display lists to be generated.

DESCRIPTION
$\text{glGenLists}$ has one argument, range. It returns an integer $n$ such that range contiguous empty 
display lists, named $n$, $n+1$, ..., $n+\text{range}-1$, are created. If range is zero, if there is no group of range 
contiguous names available, or if any error is generated, no display lists are generated, and zero is 
returned.

ERRORS
$\text{GL_INVALID_VALUE}$ is generated if range is negative.

$\text{GL_INVALID_OPERATION}$ is generated if $\text{glGenLists}$ is called between a call to $\text{glBegin}$ and the 
corresponding call to $\text{glEnd}$.

ASSOCIATED GETS
$\text{glIsList}$

SEE ALSO
"glGenList"
\texttt{glGet}

\textbf{NAME}

\texttt{glGetBooleanv}, \texttt{glGetDoublev}, \texttt{glGetFloatv}, \texttt{glGetIntegerv} — return the value or values of a
selected parameter

\textbf{C SPECIFICATION}

\begin{verbatim}
void glGetBooleanv(GLenum pname, GLboolean *params);
void glGetDoublev(GLenum pname, GLdouble *params);
void glGetFloatv(GLenum pname, GLfloat *params);
void glGetIntegerv(GLenum pname, GLint *params);
\end{verbatim}

\textbf{PARAMETERS}

\begin{itemize}
  \item \texttt{pname} Specifies the parameter value to be returned. The symbolic constants in the list below are
        accepted.
  \item \texttt{params} Returns the value or values of the specified parameter.
\end{itemize}

\textbf{DESCRIPTION}

These four commands return values for simple state variables in GL. \texttt{pname} is a symbolic constant indicating the state variable to be returned, and \texttt{params} is a pointer to an array of the indicated type in which to place the returned data.

Type conversion is performed if \texttt{params} has a different type than the state variable value being requested. If \texttt{glGetBooleanv} is called, a floating-point or integer value is converted to \texttt{GL_FALSE} if and only if it is zero. Otherwise, it is converted to \texttt{GL_TRUE}. If \texttt{glGetIntegerv} is called, Boolean values are returned as \texttt{GL_TRUE} or \texttt{GL_FALSE}, and most floating-point values are rounded to the nearest integer value. Floating-point colors and normals, however, are returned with a linear mapping that maps 1.0 to the most positive representable integer value, and −1.0 to the most negative representable integer value. If \texttt{glGetFloatv} or \texttt{glGetDoublev} is called, Boolean values are returned as \texttt{GL_TRUE} or \texttt{GL_FALSE}, and integer values are converted to floating-point values.

The following symbolic constants are accepted by \texttt{pname}

\begin{itemize}
  \item \texttt{GL_ACCUM_ALPHA_BITS} \hspace{1cm} params returns one value, the number of alpha bitplanes in the accumulation buffer.
  \item \texttt{GL_ACCUM_BLUE_BITS} \hspace{1cm} params returns one value, the number of blue bitplanes in the accumulation buffer.
  \item \texttt{GL_ACCUM_CLEAR_VALUE} \hspace{1cm} params returns four values: the red, green, blue, and alpha values used to clear the accumulation buffer. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See \texttt{glClearAccum}.
  \item \texttt{GL_ACCUM_GREEN_BITS} \hspace{1cm} params returns one value, the number of green bitplanes in the accumulation buffer.
  \item \texttt{GL_ACCUM_RED_BITS} \hspace{1cm} params returns one value, the number of red bitplanes in the accumulation buffer.
  \item \texttt{GL_ALPHA_BITS} \hspace{1cm} params returns one value, the number of alpha bitplanes in each color buffer.
  \item \texttt{GL_ALPHA_SCALE} \hspace{1cm} params returns one value, the alpha scale factor used during pixel transfers. See \texttt{glPixelTransfer}.
  \item \texttt{GL_ALPHA_TEST} \hspace{1cm} params returns a single Boolean value indicating whether alpha testing of fragments is enabled. See \texttt{glAlphaFunc}.
  \item \texttt{GL_ALPHA_TEST_FUNC} \hspace{1cm} params returns a single value, the symbolic name of the alpha test function. See \texttt{glAlphaFunc}.
  \item \texttt{GL_ALPHA_TEST_REF} \hspace{1cm} params returns one value, the reference value for the alpha test. See \texttt{glAlphaFunc}.
  \item \texttt{GL_ATTRIB_STACK_DEPTH} \hspace{1cm} params returns one value, the depth of the attribute stack. If the stack is empty, zero is returned. See \texttt{glPushAttrib}.
  \item \texttt{GL_AUTO_NORMAL} \hspace{1cm} params returns a single Boolean value indicating whether 2-D map evaluation automatically generates surface normals. See \texttt{glMap2}.
  \item \texttt{GL_AUX_BUFFERS} \hspace{1cm} params returns one value, the number of auxiliary color buffers.
  \item \texttt{GL_BLEND} \hspace{1cm} params returns a single Boolean value indicating whether blending is enabled. See \texttt{glBlendFunc}.
  \item \texttt{GL_BLEND_DST} \hspace{1cm} params returns one value, the symbolic constant identifying the destination blend function. See \texttt{glBlendFunc}.
  \item \texttt{GL_BLEND_SRC} \hspace{1cm} params returns one value, the symbolic constant identifying the source blend function. See \texttt{glBlendFunc}.
  \item \texttt{GL_BLUE_BIAS} \hspace{1cm} params returns one value, the blue bias factor used during pixel transfers. See \texttt{glPixelTransfer}.
  \item \texttt{GL_BLUE_BITS} \hspace{1cm} params returns one value, the number of blue bitplanes in each color buffer.
  \item \texttt{GL_BLUE_SCALE} \hspace{1cm} params returns one value, the blue scale factor used during pixel transfers. See \texttt{glPixelTransfer}.
  \item \texttt{GL_CLIP_PLANE} \hspace{1cm} params returns a single Boolean value indicating whether the specified clipping plane is enabled. See \texttt{glClipPlane}.
  \item \texttt{GL_COLOR_CLEAR_VALUE} \hspace{1cm} params returns four values: the red, green, blue, and alpha values used to clear the color buffers. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See \texttt{glClearColor}.
  \item \texttt{GL_COLOR_MATERIAL} \hspace{1cm} params returns a single Boolean value indicating whether one or more material parameters are tracking the current color. See \texttt{glColorMaterial}.
  \item \texttt{GL_COLOR_MATERIAL_FACE} \hspace{1cm} params returns one value, the number of blue bitplanes in each color buffer.
GL_DEPTH_BITS
params returns one value, the number of bitplanes in the depth buffer.

GL_DEPTH_CLEAR_VALUE
params returns one value, the value that is used to clear the depth buffer. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glClearDepth".

GL_DEPTH_FUNC
params returns one value, the symbolic constant that indicates the depth comparison function. See "glDepthFunc".

GL_DEPTH_RANGE
params returns two values: the near and far mapping limits for the depth buffer. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glDepthRange".

GL_DEPTH_SCALE
returns a single Boolean value indicating whether depth testing of fragments is enabled. See "glDepthTest".

GL_DITHER
params returns a single Boolean value indicating whether dithering of fragment colors and indices is enabled.

GL_DOUBLEBUFFER
params returns a single Boolean value indicating whether double buffering is supported.

GL_DRAW_BUFFER
params returns one value, a symbolic constant indicating which buffers are being drawn to. See "glDrawBuffer".

GL_EDGE_FLAG
params returns a single Boolean value indicating which buffers are being written to. See "glEdgeFlag".

GL_FOG
params returns a single Boolean value indicating whether fogging is enabled. See "glFog".

GL_FOG_COLOR
params returns four values: the red, green, blue, and alpha components of the fog color. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glFog".

GL_FOG_DENSITY
params returns one value, the fog density parameter. See "glFog".

GL_FOG_INDEX
params returns one value, the end factor for the linear fog equation. See "glFog".

GL_FOG_HINT
params returns one value, a symbolic constant indicating the mode of the fog hint. See "glHint".

GL_INDEX
returns a single Boolean value indicating whether the current raster position is valid. See "glRasterPos".

GL_INDEX
returns four values: the x, y, z, and w components of the current raster position. See "glTexImage".

GL_INDEX
returns four values: the current texture coordinates. See "glTexCoord".

GL_INDEX
returns a single Boolean value indicating whether the current raster position is a valid. See "glRasterPos".

GL_INDEX
returns four values: the current raster texture coordinates. See "glTexImage".

GL_INDEX
returns four values: the current texture coordinates. See "glTexCoord".

GL_INDEX
returns one value, a symbolic constant indicating which materials have a parameter that is tracking the current color. See "glColorMaterial".

GL_INDEX
returns one value, a symbolic constant indicating which material parameters are tracking the current color. See "glColorMaterial".

GL_INDEX
returns one value, a symbolic constant indicating which polygon faces are to be culled. See "glCullFace".

GL_INDEX
returns a single Boolean value indicating if the depth buffer is enabled for writing. See "glDepthMask".

GL_INDEX
returns one value, the distance from the eye to the current raster position. See "glRasterPos".

GL_INDEX
returns three values: the x, y, and z values of the current normal. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glNormal".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current normal. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glColor".

GL_INDEX
returns one value, the current color index. See "glIndex".

GL_INDEX
returns one value, the current color index. See "glIndex".

GL_INDEX
returns four values: the x, y, z, and w components of the current color. See "glColor".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current color. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glColor".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current color. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glColor".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current index. See "glIndex".

GL_INDEX
returns four values: the x, y, z, and w components of the current index. See "glIndex".

GL_INDEX
returns four values: the x, y, z, and w components of the current raster position. See "glRasterPos".

GL_INDEX
returns one value, the distance from the eye to the current raster position. See "glRasterPos".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current raster position. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glRasterPos".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current raster position. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glRasterPos".

GL_INDEX
returns four values: the red, green, blue, and alpha values of the current raster position. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and −1.0 returns the most negative representable integer value. See "glRasterPos".

GL_INDEX
returns four values: the x, y, z, and w components of the current raster position. See "glRasterPos".

GL_INDEX
returns four values: the x, y, z, and w components of the current raster position. See "glRasterPos".

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returns four values: the x, y, z, and w components of the current raster position. See "glRasterPos".

GL_INDEX
returns four values: the x, y, z, and w components of the current raster position. See "glRasterPos".
GL_FOG_MODE
params returns one value, a symbolic constant indicating which fog equation is selected. See "glFog".

GL_FOG_START
params returns one value, the start factor for the linear fog equation. See "glFog".

GL_FRONT_FACE
params returns one value, a symbolic constant indicating whether clockwise or counterclockwise polygon winding is treated as front-facing. See "glFrontFace".

GL_GREEN_BIAS
params returns one value, the green bias factor used during pixel transfers. See "glPixelTransfer".

GL_GREEN_BITS
params returns one value, the number of green bitplanes in each color buffer. See "glPixelTransfer".

GL_GREEN_SCALE
params returns one value, the green scale factor used during pixel transfers. See "glPixelTransfer".

GL_INDEX_BITS
params returns one value, the number of bitplanes in each color index buffer. See "glPixelTransfer".

GL_INDEX_CLEAR_VALUE
params returns one value, the color index used to clear the color index buffers. See "glPixelTransfer".

GL_INDEX_MODE
params returns a single Boolean value indicating whether the GL is in color index mode (true) or RGBA mode (false).

GL_INDEX_OFFSET
params returns one value, the offset added to color and stencil indices during pixel transfers. See "glPixelTransfer".

GL_INDEX_SHIFT
params returns one value, the amount that color and stencil indices are shifted during pixel transfers. See "glPixelTransfer".

GL_INDEX_WRITEMASK
params returns one value, a mask indicating which bitplanes of each color index buffer can be written. See "glIndexMask".

GL_LIGHT
params returns a single Boolean value indicating whether the specified light is enabled. See "glLight" and "glLightModel".

GL_LIGHTING
params returns a single Boolean value indicating whether lighting is enabled. See "glLightModel".

GL_LIGHT_MODEL_AMBIENT
params returns four values: the red, green, blue, and alpha components of the ambient intensity of the entire scene. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and -1.0 returns the most negative representable integer value. See "glLightModel".

GL_LIGHT_MODEL_LOCAL_VIEWER
params returns a single Boolean value indicating whether specular reflection calculations treat the viewer as being local to the scene. See "glLightModel".

GL_LIGHT_MODEL_TWO_SIDE
params returns a single Boolean value indicating whether separate materials are used to compute lighting for front- and back-facing polygons. See "glLightModel".

GL_LINE_SMOOTH
params returns a single Boolean value indicating whether antialiasing of lines is enabled. See "glLineWidth".

GL_LINE_SMOOTH_HINT
params returns one value, a symbolic constant indicating the mode of the line antialiasing hint. See "glHint".

GL_LINE_STIPPLE
params returns one value, a symbolic constant indicating whether stippling of lines is enabled. See "glLineStipple".

GL_LINE_STIPPLE_PATTERN
params returns one value, the 16-bit line stipple pattern. See "glLineStipple".

GL_LINE_STIPPLE_REPEAT
params returns one value, the line stipple repeat factor. See "glLineStipple".

GL_LINE_WIDTH
params returns one value, the line width as specified with glLineWidth.

GL_LINE_WIDTH_GRANULARITY
returns one value, the line width difference between adjacent supported widths for antialiased lines. See "glLineWidth".

GL_LINE_WIDTH_RANGE
returns two values: the smallest and largest supported widths for antialiased lines. See "glLineWidth".

GL_LIST_BASE
params returns one value, the base offset added to all names in arrays presented to glCallLists. See "glListBase".

GL_LIST_INDEX
params returns one value, the name of the display list currently under construction. Zero is returned if no display list is currently under construction. See "glNewList".

GL_LIST_MODE
params returns one value, a symbolic constant indicating the construction mode of the display list currently being constructed. See "glNewList".

GL_LOGIC_OP
params returns a single Boolean value indicating whether fragment indexes are merged into the framebuffer using a logical operation. See "glLogicOp".

GL_LOGIC_OP_MODE
params returns a single Boolean value indicating whether fragment indexes are merged into the framebuffer using a logical operation. See "glLogicOp".

GL_MAP1_COLOR_4
returns a single Boolean value indicating whether separate materials are used to compute lighting for front- and back-facing polygons. See "glMap1".

GL_MAP1_GRID_DOMAIN
returns two values: the endpoints of the 1-D map's grid domain. See "glMapGrid".

GL_MAP1_GRID_SEGMENTS
returns two values: the smallest and largest supported widths for antialiased lines. See "glLineWidth".

GL_MAP1_INDEX
params returns one value, the number of partitions in the 1-D map's grid domain. See "glMapGrid".

GL_MAP1_NORMAL
params returns a single Boolean value indicating whether 1D evaluation generates normals. See "glMap1".

GL_MAP1_TEXTURE_COORD_1
params returns two values: the endpoints of the 1-D texture coordinate domain. See "glMapGrid".

GL_MAP1_TEXTURE_COORD_2
params returns a single Boolean value indicating whether 1D evaluation generates 2D texture coordinates. See "glMap1".

GL_MAP1_TEXTURE_COORD_3
params returns a single Boolean value indicating whether 1D evaluation generates 2D texture coordinates. See "glMap1".
params returns a single Boolean value indicating whether 1D evaluation generates 3D texture coordinates. See "glMap1".

GL_MAP1_TEXTURE_COORD_4
params returns a single Boolean value indicating whether 1D evaluation generates 3D texture coordinates. See "glMap1".

GL_MAP1_VERTEX_3
params returns a single Boolean value indicating whether 1D evaluation generates 3D vertex coordinates. See "glMap1".

GL_MAP1_VERTEX_4
params returns a single Boolean value indicating whether 1D evaluation generates 4D vertex coordinates. See "glMap1".

GL_MAP2_COLOR_4
params returns a single Boolean value indicating whether 2D evaluation generates colors. See "glMap2".

GL_MAP2_GRID_DOMAIN
params returns four values: the endpoints of the 2-D map's i and j grid domains. See "glMapGrid".

GL_MAP2_GRID_SEGMENTS
params returns two values: the number of partitions in the 2-D map's i and j grid domains. See "glMapGrid".

GL_MAP2_INDEX
params returns a single Boolean value indicating whether 2D evaluation generates color indices. See "glMap2".

GL_MAP2_NORMAL
params returns a single Boolean value indicating whether 2D evaluation generates normals. See "glMap2".

GL_MAP2_TEXTURE_COORD_1
params returns a single Boolean value indicating whether 2D evaluation generates 1D texture coordinates. See "glMap2".

GL_MAP2_TEXTURE_COORD_2
params returns a single Boolean value indicating whether 2D evaluation generates 2D texture coordinates. See "glMap2".

GL_MAP2_TEXTURE_COORD_3
params returns a single Boolean value indicating whether 2D evaluation generates 3D texture coordinates. See "glMap2".

GL_MAP2_TEXTURE_COORD_4
params returns a single Boolean value indicating whether 2D evaluation generates 4D texture coordinates. See "glMap2".

GL_MATRIX_MODE
params returns a single Boolean value indicating which matrix stack is currently the target of all matrix operations. See "glMatrixMode".

GL_MAX_ATTRIB_STACK_DEPTH
params returns one value, the maximum supported depth of the attribute stack. See "glPushAttrib".

GL_MAX_CLIP_PLANES
params returns one value, the maximum number of application-defined clipping planes. See "glClipPlane".

GL_MAX_EVAL_ORDER
params returns one value, the maximum equation order supported by 1-D and 2-D evaluators. See "glMap1" and "glMap2".

GL_MAX_LIGHTS
params returns one value, the maximum number of lights. See "glLight".

GL_MAX_LIST_NESTING
params returns one value, the maximum recursion depth allowed during display-list traversal. See "glCallList".

GL_MAX_MODELVIEW_STACK_DEPTH
params returns one value, the maximum supported depth of the modelview matrix stack. See "glPushMatrix".

GL_MAX_NAME_STACK_DEPTH
params returns one value, the maximum supported depth of the selection name stack. See "glPushMatrix".

GL_MAX_PIXEL_MAP_TABLE
params returns one value, the maximum supported size of a glPixelMap lookup table. See "glPixelMap".

GL_MAX_PROJECTION_STACK_DEPTH
params returns one value, the maximum supported depth of the projection matrix stack. See "glPushMatrix".

GL_MAX_TEXTURE_SIZE
params returns one value, the maximum width or height of any texture image (without borders). See "glTexImage1D" and "glTexImage2D".

GL_MAX_TEXTURE_STACK_DEPTH
params returns one value, the maximum supported depth of the texture matrix stack. See "glPushMatrix".

GL_MAX_VIEWPORT_DIMS
params returns two values: the maximum supported width and height of the viewport. See "glViewport".

GL_MODELVIEW_MATRIX
params returns sixteen values: the modelview matrix on the top of the modelview matrix stack. See "glPushMatrix".

GL_MODELVIEW_STACK_DEPTH
params returns one value, the number of matrices on the modelview matrix stack. See "glPushMatrix".

GL_NAME_STACK_DEPTH
params returns one value, the number of names on the selection name stack. See "glPushMatrix".

GL_NORMALIZE
params returns a single Boolean value indicating whether normals are automatically replaced by table lookup during pixel transfers. See "glPixelTransfer".

GL_PACK_ALIGNMENT
params returns one value, the byte alignment used for writing pixel data to memory. See "glPixelStore".

GL_PACK_LSB_FIRST
params returns a single Boolean value indicating whether single-bit pixels being written to memory are written first to the least significant bit of each unsigned byte. See "glPixelStore".
GL_PACK_ROW_LENGTH
params returns one value, the row length used for writing pixel data to memory. See "glPixelStore".

GL_PACK_SKIP_PIXELS
params returns one value, the number of pixel locations skipped before the first pixel is written into memory. See "glPixelStore".

GL_PACK_SKIP_ROWS
params returns one value, the number of rows of pixel locations skipped before the first pixel is written into memory. See "glPixelStore".

GL_PACK_SWAP_BYTES
params returns a single Boolean value indicating whether the bytes of two-byte and four-byte pixel indices and components are swapped before being written to memory. See "glPixelStore".

GL_PERSPECTIVE_CORRECTION_HINT
params returns one value, a symbolic constant indicating the mode of the perspective correction hint. See "glHint".

GL_PIXEL_MAP_A_TO_A_SIZE
params returns one value, the size of the alpha-to-alpha pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_B_TO_B_SIZE
params returns one value, the size of the blue-to-blue pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_G_TO_G_SIZE
params returns one value, the size of the green-to-green pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_I_TO_A_SIZE
params returns one value, the size of the index-to-alpha pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_I_TO_B_SIZE
params returns one value, the size of the index-to-blue pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_I_TO_G_SIZE
params returns one value, the size of the index-to-green pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_I_TO_I_SIZE
params returns one value, the size of the index-to-index pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_I_TO_R_SIZE
params returns one value, the size of the index-to-red pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_R_TO_R_SIZE
params returns one value, the size of the red-to-red pixel translation table. See "glPixelMap".

GL_PIXEL_MAP_S_TO_S_SIZE
params returns one value, the size of the stencil-to-stencil pixel translation table. See "glPixelMap".

GL_POINT_SIZE
params returns one value, the point size as specified by glPointSize.

GL_POINT_SIZE_GRANULARITY
params returns one value, the size difference between adjacent supported sizes for antialiased points. See "glPointSize".

GL_POINT_SIZE_RANGE
params returns two values: the smallest and largest supported sizes for antialiased points. See "glPointSize".

GL_POINT_SMOOTH
params returns a single Boolean value indicating whether antialiasing of points is enabled. See "glPointSize".

GL_POINT_SMOOTH_HINT
params returns one value, a symbolic constant indicating the mode of the point antialiasing hint. See "glHint".

GL_POLYGON_MODE
params returns two values: symbolic constants indicating whether front-facing and back-facing polygons are rasterized as points, lines, or filled polygons. See "glPolygonMode".

GL_POLYGON_SMOOTH
params returns a single Boolean value indicating whether antialiasing of polygons is enabled. See "glPolygonMode".

GL_POLYGON_SMOOTH_HINT
params returns one value, a symbolic constant indicating the mode of the polygon antialiasing hint. See "glHint".

GL_POLYGON_STIPPLE
params returns a single Boolean value indicating whether stippling of polygons is enabled. See "glPolygonStipple".

GL_PROJECTION_MATRIX
params returns sixteen values: the projection matrix on the top of the projection matrix stack. See "glPushMatrix".

GL_READ_BUFFER
params returns one value, the number of matrices on the projection matrix stack. See "glPixelMap".

GL_READ_BUFFER
params returns one value, a symbolic constant indicating which color buffer is selected for reading. See "glReadPixels" and "glAccum".

GL_RED_BIAS
params returns one value, the red bias factor used during pixel transfers.

GL_RED_BITS
params returns one value, the number of red bitplanes in each color buffer.

GL_RED_SCALE
params returns one value, the red scale factor used during pixel transfers. See "glPixelTransfer".

GL_RENDER_MODE
params returns one value, a symbolic constant indicating whether the GL is in render, select, or feedback mode. See "glRenderMode".

GL_RGBA_MODE
params returns a single Boolean value indicating whether the GL is in RGBA mode (true) or color index mode (false). See "glColor".

GL_SCISSOR_BOX
params returns four values: the x and y window coordinates of the scissor box, follow by its width and height. See "glScissor".

GL_SCISSOR_TEST
params returns a single Boolean value indicating whether scissoring is enabled. See "glScissor".

GL_SHADE_MODEL
params returns one value, a symbolic constant indicating whether the shading mode is flat or smooth. See "glShadeModel".

GL_STENCIL_BITS
params returns one value, the number of bitplanes in the stencil buffer.

GL_STENCIL_CLEAR_VALUE
params returns one value, the index to which the stencil bitplanes are cleared. See
GL_STENCIL_FAIL
params returns one value, a symbolic constant indicating what action is taken when the stencil test fails. See "glStencilOp".

GL_STENCIL_FUNC
params returns one value, a symbolic constant indicating what function is used to compare the stencil reference value with the stencil buffer value. See "glStencilFunc".

GL_STENCIL_PASS_DEPTH_FAIL
params returns one value, a symbolic constant indicating what action is taken when the stencil test passes, but the depth test fails. See "glStencilOp".

GL_STENCIL_PASS_DEPTH_PASS
params returns one value, a symbolic constant indicating what action is taken when the stencil test passes and the depth test passes. See "glStencilOp".

GL_STENCIL_REF
params returns one value, the reference value that is compared with the contents of the stencil buffer. See "glStencilFunc".

GL_STENCIL_TEST
params returns a single Boolean value indicating whether stencil testing of fragments is enabled. See "glStencilFunc" and "glStencilOp".

GL_STENCIL_VALUE_MASK
params returns one value, the mask that controls writing of the stencil bitplanes. See "glStencilMask".

GL_STENCIL_WRITEMASK
params returns one value, a symbolic constant indicating what action is taken when the stencil buffer is written. See "glStencilOp".

GL_STEREO
params returns a single Boolean value indicating whether stereo buffers (left and right) are supported.

GL_SUBPIXEL_BITS
params returns one value, an estimate of the number of bits of subpixel resolution that are used to position rasterized geometry in window coordinates.

GL_TEXTURE_1D
params returns a single Boolean value indicating whether 1D texture mapping is enabled. See "glTexImage1D".

GL_TEXTURE_2D
params returns a single Boolean value indicating whether 2D texture mapping is enabled. See "glTexImage2D".

GL_TEXTURE_ENV_COLOR
params returns four values: the red, green, blue, and alpha values of the texture environment color. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and -1.0 returns the most negative representable integer value. See "glTexEnv".

GL_TEXTURE_ENV_MODE
params returns one value, a symbolic constant indicating what texture environment function is currently selected. See "glTexEnv".

GL_TEXTURE_GEN_S
params returns a single Boolean value indicating whether automatic generation of the S texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_GEN_T
params returns a single Boolean value indicating whether automatic generation of the T texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_GEN_R
params returns a single Boolean value indicating whether automatic generation of the R texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_GEN_Q
params returns a single Boolean value indicating whether automatic generation of the Q texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_MATRIX
params returns sixteen values: the texture matrix on the top of the texture matrix stack. See "glPushMatrix".

GL_TEXTURE_STACK_DEPTH
params returns one value, the number of matrices on the texture matrix stack. See "glPushMatrix".

GL_STENCIL_FAIL
params returns one value, a symbolic constant indicating what action is taken when the stencil test fails. See "glStencilOp".

GL_STENCIL_FUNC
returns a single Boolean value indicating whether stencil testing of fragments is enabled. See "glStencilFunc" and "glStencilOp".

GL_STENCIL_PASS_DEPTH_FAIL
returns one value, a symbolic constant indicating what action is taken when the stencil test passes, but the depth test fails. See "glStencilOp".

GL_STENCIL_PASS_DEPTH_PASS
returns one value, a symbolic constant indicating what action is taken when the stencil test passes and the depth test passes. See "glStencilOp".

GL_STENCIL_REF
returns one value, the reference value that is compared with the contents of the stencil buffer. See "glStencilFunc".

GL_STENCIL_TEST
returns a single Boolean value indicating whether stencil testing of fragments is enabled. See "glStencilFunc" and "glStencilOp".

GL_STENCIL_VALUE_MASK
returns one value, the mask that controls writing of the stencil bitplanes. See "glStencilMask".

GL_STENCIL_WRITEMASK
returns one value, a symbolic constant indicating what action is taken when the stencil buffer is written. See "glStencilOp".

GL_STENCIL_WRITEMASK
returns one value, the mask that controls writing of the stencil bitplanes. See "glStencilMask".

GL_STEREO
returns a single Boolean value indicating whether stereo buffers (left and right) are supported.

GL_SUBPIXEL_BITS
returns one value, an estimate of the number of bits of subpixel resolution that are used to position rasterized geometry in window coordinates.

GL_TEXTURE_1D
returns a single Boolean value indicating whether 1D texture mapping is enabled. See "glTexImage1D".

GL_TEXTURE_2D
returns a single Boolean value indicating whether 2D texture mapping is enabled. See "glTexImage2D".

GL_TEXTURE_ENV_COLOR
returns four values: the red, green, blue, and alpha values of the texture environment color. Integer values, if requested, are linearly mapped from the internal floating-point representation such that 1.0 returns the most positive representable integer value, and -1.0 returns the most negative representable integer value. See "glTexEnv".

GL_TEXTURE_ENV_MODE
returns one value, a symbolic constant indicating what texture environment function is currently selected. See "glTexEnv".

GL_TEXTURE_GEN_S
returns a single Boolean value indicating whether automatic generation of the S texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_GEN_T
returns a single Boolean value indicating whether automatic generation of the T texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_GEN_R
returns a single Boolean value indicating whether automatic generation of the R texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_GEN_Q
returns a single Boolean value indicating whether automatic generation of the Q texture coordinate is enabled. See "glTexGen".

GL_TEXTURE_MATRIX
returns sixteen values: the texture matrix on the top of the texture matrix stack. See "glPushMatrix".

GL_TEXTURE_STACK_DEPTH
returns one value, the number of matrices on the texture matrix stack. See "glPushMatrix".

GL_UNPACK_ALIGNMENT
returns one value, the byte alignment used for reading pixel data from memory. See "glPixelStore".

GL_UNPACK_LSB_FIRST
returns a single Boolean value indicating whether single−bit pixels being read from memory are read first from the least significant bit of each unsigned byte. See "glPixelStore".

GL_UNPACK_ROW_LENGTH
returns one value, the row length used for reading pixel data from memory. See "glPixelStore".

GL_UNPACK_SKIP_PIXELS
returns one value, the number of pixel locations skipped before the first pixel is read from memory. See "glPixelStore".

GL_UNPACK_SKIP_ROWS
returns one value, the number of rows of pixel locations skipped before the first pixel is read from memory. See "glPixelStore".

GL_UNPACK_SWAP_BYTES
returns a single Boolean value indicating whether the bytes of two−byte and four−byte pixel indices and components are swapped after being read from memory. See "glPixelStore".

GL_VIEWPORT
returns four values: the x and y window coordinates of the viewport, follow by its width and height. See "glViewport".

GL_ZOOM_X
returns one value, the x pixel zoom factor. See "glPixelZoom".

GL_ZOOM_Y
returns one value, the y pixel zoom factor. See "glPixelZoom".

Many of the Boolean parameters can also be queried more easily using glIsEnabled.

ERRORS
GL_INVALID_ENUM is generated if pname is not an accepted value.

GL_INVALID_OPERATION is generated if glIsEnabled is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO
"glGetClipPlane", "glGetError", "glGetLight", "glGetMap", "glGetMaterial", "glGetPixelMap", "glGetPolygonStipple", "glGetString", "glGetTexImage", "glGetTexEnv", "glGetTexGen", "glIsEnabled"
**glGetClipPlane**

**NAME**

`glGetClipPlane` — return the coefficients of the specified clipping plane

**C SPECIFICATION**

```c
void glGetClipPlane( GLenum plane, GLdouble *equation )
```

**PARAMETERS**

- `plane`: Specifies a clipping plane. The number of clipping planes depends on the implementation, but at least six clipping planes are supported. They are identified by symbolic names of the form `GL_CLIP_PLANEi` where `0 ≤ i < GL_MAX_CLIP_PLANES`.

- `equation`: Returns four double-precision values that are the coefficients of the plane equation of `plane` in eye coordinates.

**DESCRIPTION**

`glGetClipPlane` returns in `equation` the four coefficients of the plane equation for `plane`.

**NOTES**

It is always the case that `GL_CLIP_PLANEi = GL_CLIP_PLANE0 + i`. If an error is generated, no change is made to the contents of `equation`.

**ERRORS**

- `GL_INVALID_ENUM` is generated if `plane` is not an accepted value.
- `GL_INVALID_OPERATION` is generated if `glGetClipPlane` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**SEE ALSO**

`glClipPlane`

**glGetError**

**NAME**

`glGetError` — return error information

**C SPECIFICATION**

```c
GLenum glGetError( void )
```

**DESCRIPTION**

`glGetError` returns the value of the error flag. Each detectable error is assigned a numeric code and symbolic name. When an error occurs, the error flag is set to the appropriate error code value. No other errors are recorded until `glGetError` is called, the error code is returned, and the flag is reset to `GL_NO_ERROR`. If a call to `glGetError` returns `GL_NO_ERROR`, there has been no detectable error since the last call to `glGetError`, or since the GL was initialized.

To allow for distributed implementations, there may be several error flags. If any single error flag has recorded an error, the value of that flag is returned and that flag is reset to `GL_NO_ERROR` when `glGetError` is called. If more than one flag has recorded an error, `glGetError` returns and clears an arbitrary error flag value. Thus, `glGetError` should always be called in a loop, until it returns `GL_NO_ERROR`, if all error flags are to be reset.

Initially, all error flags are set to `GL_NO_ERROR`. The currently defined errors are as follows:

- `GL_NO_ERROR` — No error has been recorded. The value of this symbolic constant is guaranteed to be zero.
- `GL_INVALID_ENUM` — An unacceptable value is specified for an enumerated argument. The offending command is ignored, having no side effect other than to set the error flag.
- `GL_INVALID_VALUE` — A numeric argument is out of range. The offending command is ignored, having no side effect other than to set the error flag.
- `GL_INVALID_OPERATION` — The specified operation is not allowed in the current state. The offending command is ignored, having no side effect other than to set the error flag.
- `GL_STACK_OVERFLOW` — This command would cause a stack overflow. The offending command is ignored, having no side effect other than to set the error flag.
- `GL_STACK_UNDERFLOW` — This command would cause a stack underflow. The offending command is ignored, having no side effect other than to set the error flag.
- `GL_OUT_OF_MEMORY` — There is not enough memory left to execute the command. The state of the GL is undefined, except for the state of the error flags, after this error is recorded. When an error flag is set, results of a GL operation are undefined only if `GL_OUT_OF_MEMORY` has occurred. In all other cases, the command generating the error is ignored and has no effect on the GL state or frame buffer contents.

**ERRORS**

- `GL_INVALID_OPERATION` is generated if `glGetError` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**glGetLight**

**NAME**

`glGetLightfv`, `glGetLightiv` — return light source parameter values

**C SPECIFICATION**

```c
void glGetLightfv( GLenum light, GLenum pname, GLfloat *params )
void glGetLightiv( GLenum light, GLenum pname, GLint *params )
```

**PARAMETERS**

- `light`: Specifies a light source. The number of possible lights depends on the
implementation, but at least eight lights are supported. They are identified by symbolic names of the form GL_LIGHTi, where 0 ≤ i < GL_MAX_LIGHTS.

Specifies a light source parameter for light. Accepted symbolic names are GL_AMBIENT, GL_DIFFUSE, GL_SPECULAR, GL_POSITION, GL_SPOT_DIRECTION, GL_SPOT_EXPONENT, GL_SPOT_CUTOFF, GL_CONSTANT_ATTENUATION, GL_LINEAR_ATTENUATION, and GL_QUADRATIC_ATTENUATION.

returns a single integer or floating-point value representing the spot cutoff angle of the light. An integer value, when requested, is computed by rounding the internal floating-point representation to the nearest integer.

GL_CONSTANT_ATTENUATION
returns a single integer or floating-point value representing the constant (not distance related) attenuation of the light. An integer value, when requested, is computed by rounding the internal floating-point representation to the nearest integer.

GL_LINEAR_ATTENUATION
returns a single integer or floating-point value representing the linear attenuation of the light. An integer value, when requested, is computed by rounding the internal floating-point representation to the nearest integer.

GL_QUADRATIC_ATTENUATION
returns a single integer or floating-point value representing the quadratic attenuation of the light. An integer value, when requested, is computed by rounding the internal floating-point representation to the nearest integer.

NOTES
It is always the case that GL_LIGHTi = GL_LIGHT0 + i.

If an error is generated, no change is made to the contents of params.

ERRORS
GL_INVALID_ENUM is generated if light or pname is not an accepted value.

GL_INVALID_OPERATION is generated if glGetLight is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO
"glLight"
GL_MAP2_NORMAL, GL_MAP2_TEXTURE_COORD_1, GL_MAP2_TEXTURE_COORD_2, GL_MAP2_TEXTURE_COORD_3, GL_MAP2_TEXTURE_COORD_4, GL_MAP2_VERTEX_3, and GL_MAP2_VERTEX_4.

query Specifies which parameter to return. Symbolic names GL_COEFF, GL_ORDER, and GL_DOMAIN are accepted.

v Returns the requested data.

DESCRIPTION

glMap1 and glMap2 define evaluators. glGetMap returns evaluator parameters. target chooses a map, query selects a specific parameter, and v points to storage where the values will be returned.

The acceptable values for the target parameter are described in the glMap1 and glMap2 reference pages.

query can assume the following values:

GL_COEFF v returns the control points for the evaluator function. One−dimensional evaluators return order control points, and two−dimensional evaluators return order u−order control points. Each control point consists of one, two, or four integer, single−precision floating−point, or double−precision floating−point values, depending on the type of the evaluator. Two−dimensional control points are returned in row−major order, incrementing the order index quickly, and the order index after each row. Integer values, when requested, are computed by rounding the internal floating−point values to the nearest integer values.

GL_ORDER v returns the order of the evaluator function. One−dimensional evaluators return a single value, order. Two−dimensional evaluators return two values, order and order v.

GL_DOMAIN v returns the linear u and v mapping parameters. One−dimensional evaluators return two values, u1 and u2, as specified by glMap1. Two−dimensional evaluators return four values (u1, u2, v1, and v2) as specified by glMap2. Integer values, when requested, are computed by rounding the internal floating−point values to the nearest integer values.

NOTES

If an error is generated, no change is made to the contents of v.

ERRORS

GL_INVALID_ENUM is generated if either target or query is not an accepted value.

GL_INVALID_OPERATION is generated if glMap is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO

‘glEvalCoord’, ‘glMap1’, ‘glMap2’

gGetMaterial

NAME

gGetMaterialfv, glGetMaterialiv – return material parameters

c specification

void glGetMaterialfv( GLenum face, GLenum pname, GLfloat *params)

void glGetMaterialiv( GLenum face, GLenum pname, GLint *params)

PARAMETERS

face Specifies which of the two materials is being queried. GL_FRONT or GL_BACK are accepted, representing the front and back materials, respectively.

pname Specifies the material parameter to return. GL_AMBIENT, GL_DIFFUSE, GL_SPECULAR, GL_EMISSION, GL_SHININESS, and GL_COLOR_INDEXES are accepted.

params Returns the requested data.

DESCRIPTION

gGetMaterial returns in params the value or values of parameter pname of material face. Six parameters are defined:

GL_AMBIENT params returns four integer or floating−point values representing the ambient reflectance of the material. Integer values, when requested, are linearly mapped from the internal floating−point representation such that 1.0 maps to the most positive representable integer value, and −1.0 maps to the most negative representable integer value. If the internal value is outside the range [−1,1], the corresponding integer return value is undefined.

GL_DIFFUSE params returns four integer or floating−point values representing the diffuse reflectance of the material. Integer values, when requested, are linearly mapped from the internal floating−point representation such that 1.0 maps to the most positive representable integer value, and −1.0 maps to the most negative representable integer value. If the internal value is outside the range [−1,1], the corresponding integer return value is undefined.

GL_SPECULAR params returns four integer or floating−point values representing the specular reflectance of the material. Integer values, when requested, are linearly mapped from the internal floating−point representation such that 1.0 maps to the most positive representable integer value, and −1.0 maps to the most negative representable integer value. If the internal value is outside the range [−1,1], the corresponding integer return value is undefined.

GL_EMISSION params returns four integer or floating−point values representing the emitted light intensity of the material. Integer values, when requested, are linearly mapped from the internal floating−point representation such that 1.0 maps to the most positive representable integer value, and −1.0 maps to the most negative representable integer value. If the internal value is outside the range [−1,1], the corresponding integer return value is undefined.

GL_SHININESS params returns one integer or floating−point value representing the specular exponent of the material. Integer values, when requested, are computed by rounding the internal floating−point value to the nearest integer value.

GL_COLOR_INDEXES params returns three integer or floating−point values representing the ambient, diffuse, and specular indices of the material. These indices are used only for color index lighting. (The other parameters are all used only for RGBA lighting.) Integer
to the nearest integer values.

NOTES
If an error is generated, no change is made to the contents of params.

ERRORS
GL_INVALID_ENUM is generated if face or pname is not an accepted value.
GL_INVALID_OPERATION is generated if glGetMaterial is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO
"glMaterial"

NAME
glGetPixelMap, glGetPixelMapfv, glGetPixelMapuiv, glGetPixelMapusv — return the specified pixel map

C SPECIFICATION
void glGetPixelMapfv(GLenum map, GLfloat*values)
void glGetPixelMapuiv(GLenum map, GLuint*values)
void glGetPixelMapusv(GLenum map, GLushort*values)

PARAMETERS
map Specifies the name of the pixel map to return. Accepted values are
  GL_PIXEL_MAP_I_TO_I, GL_PIXEL_MAP_S_TO_S, GL_PIXEL_MAP_I_TO_R,
  GL_PIXEL_MAP_I_TO_G, GL_PIXEL_MAP_I_TO_B, GL_PIXEL_MAP_I_TO_A,
  GL_PIXEL_MAP_R_TO_R, GL_PIXEL_MAP_G_TO_G,
  GL_PIXEL_MAP_B_TO_B, and GL_PIXEL_MAP_A_TO_A.
values Returns the pixel map contents.

DESCRIPTION
Please see the "glPixelMap" reference page for a description of the acceptable values for the map parameter. glGetPixelMap returns in values the contents of the pixel map specified in map. Pixel maps are used during the execution of glReadPixels, glDrawPixels, glCopyPixels, glTexImage1D, and glTexImage2D to map color indices, stencil indices, color components, and depth components to other values.

Unsigned integer values, if requested, are linearly mapped from the internal fixed or floating-point representation such that 1.0 maps to the largest representable integer value, and 0.0 maps to zero. Return unsigned integer values are undefined if the map value was not in the range [0,1]. To determine the required size of map, call glGet with the appropriate symbolic constant.

NOTES
If an error is generated, no change is made to the contents of values.

ERRORS
GL_INVALID_ENUM is generated if map is not an accepted value.
GL_INVALID_OPERATION is generated if glGetPixelMap is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_PIXEL_MAP_I_TO_I_SIZE
glGet with argument GL_PIXEL_MAP_S_TO_S_SIZE
glGet with argument GL_PIXEL_MAP_I_TO_R_SIZE
glGet with argument GL_PIXEL_MAP_I_TO_G_SIZE
glGet with argument GL_PIXEL_MAP_I_TO_B_SIZE
glGet with argument GL_PIXEL_MAP_I_TO_A_SIZE
glGet with argument GL_PIXEL_MAP_R_TO_R_SIZE
glGet with argument GL_PIXEL_MAP_G_TO_G_SIZE
glGet with argument GL_PIXEL_MAP_B_TO_B_SIZE
glGet with argument GL_PIXEL_MAP_A_TO_A_SIZE

SEE ALSO
"glCopyPixels", "glDrawPixels", "glPixelMap", "glPixelTransfer", "glReadPixels", "glTexImage1D", "glTexImage2D"
gGetPolygonStipple

NAME
gGetPolygonStipple — return the polygon stipple pattern

C SPECIFICATION
void glGetPolygonStipple(GLubyte*mask)

PARAMETERS
mask Returns the stipple pattern.

DESCRIPTION
Please see the "glPolygonStipple" reference page for a description of the acceptable values for the mask parameter. glGetPolygonStipple returns in mask the contents of the polygon stipple pattern. The pattern is packed into memory as if glReadPixels with both height and width of 32, type of GL_BITMAP, and format of GL_COLOR_INDEX were called, and the stipple pattern were stored in an internal 32×32 color index buffer. Unlike glReadPixels however, pixel transfer operations (shift, offset, pixel map) are not applied to the returned stipple image.

NOTES
If an error is generated, no change is made to the contents of mask.

ERRORS
GL_INVALID_OPERATION is generated if glGetPolygonStipple is called between a call to
**glBegin** and the corresponding call to **glEnd**.

**SEE ALSO**
'glPixelStore', 'glPixelTransfer', 'glPolygonStipple', 'glReadPixels'

**glGetString**

**NAME**

**glGetString** — returns a string describing the current GL connection

**C SPECIFICATION**

```c
const GLubyte *glGetString ( GLenum name )
```

**PARAMETERS**

- **name** Specifies a symbolic constant, one of **GL_VENDOR**, **GL_RENDERER**, **GL_VERSION**, or **GL_EXTENSIONS**.

**DESCRIPTION**

**glGetString** returns a pointer to a static string describing some aspect of the current GL connection. **name** can be one of the following:

**GL_VENDOR**

- Returns the company responsible for this GL implementation. This name does not change from release to release.

**GL_RENDERER**

- Returns the name of the renderer. This name is typically specific to a particular configuration of a hardware platform. It does not change from release to release.

**GL_VERSION**

- Returns a version or release number.

**GL_EXTENSIONS**

- Returns a space-separated list of supported extensions to GL.

Because GL does not include queries for the performance characteristics of an implementation, it is expected that some applications will be written to recognize known platforms and will modify their GL usage based on known performance characteristics of these platforms. Strings **GL_VENDOR** and **GL_RENDERER** together uniquely specify a platform, and will not change from release to release. They should be used by such platform recognition algorithms.

The format and contents of the string that **glGetString** returns depend on the implementation, except that extension names will not include space characters and will be separated by space characters in the **GL_EXTENSIONS** string, and that all strings are null-terminated.

**NOTES**

If an error is generated, **glGetString** returns zero.

**ERRORS**

- **GL_INVALID_ENUM** is generated if **name** is not an accepted value.
- **GL_INVALID_OPERATION** is generated if **glGetString** is called between a call to **glBegin** and the corresponding call to **glEnd**.

**SEE ALSO**

'glGetTexEnv'

**glGetTexEnv**

**NAME**

**glGetTexEnv**, **glGetTexEnvv** — return texture environment parameters

**C SPECIFICATION**

```c
void glGetTexEnvfv ( GLenum target, GLenum pname, GLfloat *params )
void glGetTexEnviv ( GLenum target, GLenum pname, GLint *params )
```

**PARAMETERS**

- **target** Specifies a texture environment. Must be **GL_TEXTURE_ENV**.
- **pname** Specifies the symbolic name of a texture environment parameter. Accepted values are **GL_TEXTURE_ENV_MODE** and **GL_TEXTURE_ENV_COLOR**.
- **params** Returns the requested data.

**DESCRIPTION**

**glGetTexEnv** returns in **params** selected values of a texture environment that was specified with **glTexEnv**. **target** specifies a texture environment. Currently, only one texture environment is defined and supported: **GL_TEXTURE_ENV**.

**pname** names a specific texture environment parameter. The two parameters are as follows:

**GL_TEXTURE_ENV_MODE**

- params returns the single-valued texture environment mode, a symbolic constant.

**GL_TEXTURE_ENV_COLOR**

- params returns four integer or floating-point values that are the texture environment color. Integer values, when requested, are linearly mapped from the internal floating-point representation such that 1.0 maps to the most positive representable integer, and −1.0 maps to the most negative representable integer.

**NOTES**

If an error is generated, no change is made to the contents of **params**.

**ERRORS**

- **GL_INVALID_ENUM** is generated if **target** or **pname** is not an accepted value.
- **GL_INVALID_OPERATION** is generated if **glGetTexEnv** is called between a call to **glBegin** and the corresponding call to **glEnd**.

**SEE ALSO**

'glGetTexGen'

**glGetTexGen**

**NAME**

**glGetTexGen**, **glGetTexGenfv**, **glGetTexGeniv** — return texture coordinate generation
C SPECIFICATION

void glGetTexGendv ( GLenum target, GLint level, GLenum format, GLenum type, *pixels )

PARAMETERS

target Specifies which texture is to be obtained. target must be GL_TEXTURE_1D and GL_TEXTURE_2D.

level Specifies the level-of-detail number of the desired image. Level 0 is the base image level. Level n is the nth mipmap reduction image.

format Specifies a pixel type for the returned data. The supported types are GL_RED, GL_GREEN, GL_BLUE, GL_ALPHA, GL_RGB, GL_RGBA, GL_LUMINANCE, and GL_LUMINANCE_ALPHA.

type Specifies a pixel type for the returned data. The supported types are GL_UNSIGNED_BYTE, GL_BYTE, GL_UNSIGNED_SHORT, GL_SHORT, GL_UNSIGNED_INT, GL_INT, and GL_FLOAT.

DESCRIPTION

The function glGetTexImage returns in pixels the selected parameters of a texture coordinate generation function that was specified using glTexCoord. coord names one of the (s, t, r, q) texture coordinates, using the symbolic constant GL_S, GL_T, GL_R, or GL_Q.

NOTES

If an error is generated, no change is made to the contents of params.

ERRORS

GL_INVALID_ENUM is generated if coord or pname is not an accepted value.

GL_INVALID_OPERATION is generated if glGetTexImage is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO

"glTexCoord"

glTexImage

NAME

glTexImage — return a texture image

C SPECIFICATION

void glGetTexImage ( GLenum target, GLint level, GLenum format, GLenum type, GLvoid *pixels )

PARAMETERS

target Specifies which texture is to be obtained. GL_TEXTURE_1D and GL_TEXTURE_2D are accepted.

level Specifies the level-of-detail number of the desired image. Level 0 is the base image level. Level n is the nth mipmap reduction image.

format Specifies a pixel format for the returned data. The supported formats are GL_RED, GL_GREEN, GL_BLUE, GL_ALPHA, GL_RGB, GL_RGBA, GL_LUMINANCE, and GL_LUMINANCE_ALPHA.

type Specifies a pixel type for the returned data. The supported types are GL_UNSIGNED_BYTE, GL_BYTE, GL_UNSIGNED_SHORT, GL_SHORT, GL_UNSIGNED_INT, GL_INT, and GL_FLOAT.

pixels Returns the texture image. Should be a pointer to an array of the type specified by type.

DESCRIPTION

The function glGetTexImage returns a texture image into pixels. target specifies whether the desired texture image is one specified by glTexImage1D (GL_TEXTURE_1D) or by glTexImage2D (GL_TEXTURE_2D). level specifies the level-of-detail number of the desired image. format and type specify the format and type of the desired image array. Please see the reference pages "glTexImage1D" and "glTexImage2D" and "glDrawPixels" for a description of the acceptable values for the format and type parameters, respectively.

Operation of glGetTexImage is best understood by considering the selected internal four-component texture image to be an RGBA color buffer the size of the image. The semantics of glGetTexImage are then identical to those of glGetTexImage called with the same format and type with x and y set to zero, width set to the width of the texture image (including border if one was specified), and height set to one for 1-D images, or to the height of the texture image (including border if one was specified) for 2-D images. Because the internal texture image is an RGBA image, pixel formats GL_COLOR_INDEX, GL_STENCIL_INDEX, and GL_DEPTH_COMPONENT are not accepted, and pixel type GL_BITMAP is not accepted.

If the selected texture image does not contain four components, the following mappings are applied. Single-component textures are treated as RGBA buffers with red set to the value of component zero, alpha set to the value of component one, and green and blue set to zero. Two-component textures are treated as RGBA buffers with red set to the value of component zero, alpha set to the value of component one, and green and blue set to zero. Finally, three-component textures are treated as RGBA buffers with red set to component zero, green set to component one, blue set to component two, and alpha set to zero.

To determine the required size of pixels, use glGetTexImage to ascertain the dimensions of the internal texture image, then scale the required number of pixels by the storage required for each pixel, based on format and type. Be sure to take the pixel storage parameters into account, especially GL_PACK_ALIGNMENT.

NOTES

If an error is generated, no change is made to the contents of pixels.

ERRORS

...
GL_INVALID_ENUM is generated if target, format, or type is not an accepted value.

GL_INVALID_VALUE is generated if level is less than zero or greater than \( \log_2 \text{max} \), where max is the returned value of \( \text{GL_MAX_TEXTURE_SIZE} \).  

GL_INVALID_OPERATION is generated if \( \text{glTexImage} \) is called between a call to \( \text{glBegin} \) and the corresponding call to \( \text{glEnd} \).

ASSOCIATED GETS

\( \text{glGetTexLevelParameter} \) with argument \( \text{GL_TEXTURE_WIDTH} \)
\( \text{glGetTexLevelParameter} \) with argument \( \text{GL_TEXTURE_HEIGHT} \)
\( \text{glGetTexLevelParameter} \) with argument \( \text{GL_TEXTURE_BORDER} \)
\( \text{glGetTexLevelParameter} \) with argument \( \text{GL_TEXTURE_COMPONENTS} \)
\( \text{glGet} \) with arguments \( \text{GL_PACK_ALIGNMENT} \) and others

SEE ALSO

'glDrawPixels', 'glReadPixels', 'glTexImage1D', 'glTexImage2D'

\( \text{glGetTexLevelParameterfv} \), \( \text{glGetTexLevelParameteriv} \) — return texture parameter values for a specific level of detail

C SPECIFICATION

\( \text{void} \text{glGetTexLevelParameterfv} \) ( \( \text{GLenum} \) target, \( \text{GLint} \) level, \( \text{GLenum} \) pname, \( \text{GLfloat *} \) params)
\( \text{void} \text{glGetTexLevelParameteriv} \) ( \( \text{GLenum} \) target, \( \text{GLint} \) level, \( \text{GLenum} \) pname, \( \text{GLint *} \) params)

PARAMETERS

target Specifies the symbolic name of the target texture, either \( \text{GL_TEXTURE_1D} \) or \( \text{GL_TEXTURE_2D} \).
level Specifies the level-of-detail number of the desired image. Level 0 is the base image level. Level \( n \) is the \( n \)th mipmap reduction image.
pname Specifies the symbolic name of a texture parameter. \( \text{GL_TEXTURE_WIDTH} \), \( \text{GL_TEXTURE_HEIGHT} \), \( \text{GL_TEXTURE_COMPONENTS} \), and \( \text{GL_TEXTURE_BORDER} \) are accepted.
params Returns the requested data.

DESCRIPTION

\( \text{glGetTexLevelParameter} \) returns in params texture parameter values for a specific level-of-detail value, specified as level. target defines the target texture, either \( \text{GL_TEXTURE_1D} \) or \( \text{GL_TEXTURE_2D} \), to specify one- or two-dimensional texturing. pname specifies the texture parameter whose value or values will be returned.

The accepted parameter names are as follows:

\( \text{GL_TEXTURE_WIDTH} \) — params returns a single value, the width of the texture image. This value includes the border of the texture image.
\( \text{GL_TEXTURE_HEIGHT} \) — params returns a single value, the height of the texture image. This value includes the border of the texture image.

\( \text{GL_TEXTURE_COMPONENTS} \) — params returns a single value, the number of components in the texture image.
\( \text{GL_TEXTURE_BORDER} \) — params returns a single value, the width in pixels of the border of the texture image.

NOTES

If an error is generated, no change is made to the contents of params.

ERRORS

GL_INVALID_ENUM is generated if target or pname is not an accepted value.

GL_INVALID_VALUE is generated if level is less than zero or greater than \( \log_2 \text{max} \), where max is the returned value of \( \text{GL_MAX_TEXTURE_SIZE} \).

\( \text{GL_INVALID_OPERATION} \) is generated if \( \text{glTexImage} \) is called between a call to \( \text{glBegin} \) and the corresponding call to \( \text{glEnd} \).

SEE ALSO

'\text{glGetTexParameter}', '\text{glTexImage1D}', '\text{glTexImage2D}', '\text{glTexParameter}'

\( \text{glGetTexParameterfv} \), \( \text{glGetTexParameteriv} \) — return texture parameter values

C SPECIFICATION

\( \text{void} \text{glGetTexParameterfv} \) ( \( \text{GLenum} \) target, \( \text{GLenum} \) pname, \( \text{GLfloat *} \) params)
\( \text{void} \text{glGetTexParameteriv} \) ( \( \text{GLenum} \) target, \( \text{GLenum} \) pname, \( \text{GLint *} \) params)

PARAMETERS

target Specifies the symbolic name of the target texture, either \( \text{GL_TEXTURE_1D} \) and \( \text{GL_TEXTURE_2D} \) are accepted.
pname Specifies the symbolic name of a texture parameter. \( \text{GL_TEXTURE_MAG_FILTER} \), \( \text{GL_TEXTURE_MIN_FILTER} \), \( \text{GL_TEXTURE_WRAP_S} \), \( \text{GL_TEXTURE_WRAP_T} \), and \( \text{GL_TEXTURE_BORDER_COLOR} \) are accepted.
params Returns the texture parameters.

DESCRIPTION

\( \text{glGetTexParameter} \) returns in params the value or values of the texture parameter specified as pname. target defines the target texture, either \( \text{GL_TEXTURE_1D} \) or \( \text{GL_TEXTURE_2D} \), to specify one- or two-dimensional texturing. pname accepts the same symbols as \( \text{glTexParameter} \), with the same interpretations:

\( \text{GL_TEXTURE_MAG_FILTER} \) — Returns the single-valued texture magnification filter, a symbolic constant.
\( \text{GL_TEXTURE_MIN_FILTER} \) — Returns the single-valued texture minification filter, a symbolic constant.
GL_TEXTURE_WRAP_S
Returns the single-valued wrapping function for texture coordinates, a symbolic constant.

GL_TEXTURE_WRAP_T
Returns the single-valued wrapping function for texture coordinate, a symbolic constant.

GL_TEXTURE_BORDER_COLOR
Returns four integer or floating-point numbers that comprise the RGBA color of the texture border. Floating-point values are returned as a linear mapping of the internal floating-point representation such that 1.0 maps to the most positive representable integer and −1.0 maps to the most negative representable integer.

NOTES
If an error is generated, no change is made to the contents of params.

ERRORS
GL_INVALID_ENUM is generated if target or pname is not an accepted value.
GL_INVALID_OPERATION is generated if glGetTexParameter is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO
"glTexParameter"

glHint

NAME
glHint — specify implementation-specific hints

C SPECIFICATION
void glHint( GLenum target, GLenum mode)

PARAMETERS

| target | Specifies a symbolic constant indicating the behavior to be controlled. GL_FOG_HINT, GL_LINE_SMOOTH_HINT, GL_PERSPECTIVE_CORRECTION_HINT, GL_POINT_SMOOTH_HINT, and GL_POLYGON_SMOOTH_HINT are accepted. |
| mode | Specifies a symbolic constant indicating the desired behavior. GL_FASTEST, GL_NICEST, and GL_DONT_CARE are accepted. |

DESCRIPTION

Certain aspects of GL behavior, when there is room for interpretation, can be controlled with hints. A hint is specified with two arguments. target is a symbolic constant indicating the behavior to be controlled, and mode is another symbolic constant indicating the desired behavior. mode can be one of the following: GL_FASTEST The most efficient option should be chosen. GL_NICEST The most correct, or highest quality, option should be chosen. GL_DONT_CARE The client doesn't have a preference.

NOTES

Though the interpretation of hints depends on the implementation, glHint can be ignored.

ERRORS
GL_INVALID_ENUM is generated if either target or mode is not an accepted value.
GL_INVALID_OPERATION is generated if glHint is called between a call to glBegin and the corresponding call to glEnd.

glIndex

NAME

glIndexd, glIndexf, glIndexi, glIndexs, glIndexdv, glIndexfv, glIndexiv, glIndexsv — set the current color index

C SPECIFICATION

void glIndexd( GLdouble c)
void glIndexf( GLfloat c)
void glIndexi( GLint c)
void glIndexs( GLshort c)

PARAMETERS

GL_DONT_CARE
The client doesn't have a preference.

GL_FOG_HINT
Indicates the accuracy of fog calculation. If per-pixel fog calculation is not efficiently supported by the GL implementation, hinting GL_DONT_CARE or GL_FASTEST can result in per-vertex calculation of fog effects.

GL_LINE_SMOOTH_HINT
Indicates the sampling quality of antialiased lines. Hinting GL_NICEST can result in more pixel fragments being generated during rasterization, if a larger filter function is applied.

GL_PERSPECTIVE_CORRECTION_HINT
Indicates the quality of color and texture coordinate interpolation. If perspective-corrected parameter interpolation is not efficiently supported by the GL implementation, hinting GL_DONT_CARE or GL_FASTEST can result in simple linear interpolation of colors and/or texture coordinates.

GL_POINT_SMOOTH_HINT
Indicates the sampling quality of antialiased points. Hinting GL_NICEST can result in more pixel fragments being generated during rasterization, if a larger filter function is applied.

GL_POLYGON_SMOOTH_HINT
Indicates the sampling quality of antialiased polygons. Hinting GL_NICEST can result in more pixel fragments being generated during rasterization, if a larger filter function is applied.

NOTES

The interpretation of hints depends on the implementation. glHint can be ignored.

ERRORS
GL_INVALID_ENUM is generated if either target or mode is not an accepted value.
GL_INVALID_OPERATION is generated if glHint is called between a call to glBegin and the corresponding call to glEnd.
Specifies a pointer to a one-element array that contains the new value for the current color index.

DESCRIPTION
glIndex updates the current (single-valued) color index. It takes one argument: the new value for the current color index.

The current index is stored as a floating-point value. Integer values are converted directly to floating-point values, with no special mapping.

Index values outside the representable range of the color index buffer are not clamped. However, before an index is clamped (if enabled) and written to the frame buffer, it is converted to fixed-point format. Any bits in the integer portion of the resulting fixed-point value that do not correspond to bits in the frame buffer are masked out.

NOTES
The current index can be updated at any time. In particular, glIndex can be called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_CURRENT_INDEX

SEE ALSO
"glColor"

**glIndexMask**

NAME
glIndexMask — control the writing of individual bits in the color index buffers

C SPECIFICATION
void glIndexMask( GLuint mask )

PARAMETERS
mask — Specifies a bit mask to enable and disable the writing of individual bits in the color index buffers. Initially, the mask is all ones.

DESCRIPTION
glIndexMask controls the writing of individual bits in the color index buffers. The least significant n bits of mask, where n is the number of bits in a color index buffer, specify a mask. Wherever a one appears in the mask, the corresponding bit in the color index buffer (or buffers) is made writable.

Where a zero appears, the bit is write-protected.

This mask is used only in color index mode, and it affects only the buffers currently selected for writing (see "glDrawBuffer"). Initially, all bits are enabled for writing.

ERRORS
GL_INVALID_OPERATION is generated if glIndexMask is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_INDEX_WRITEMASK

SEE ALSO
"glColorMask", "glDepthMask", "glDrawBuffer", "glIndex", "glStencilMask"

**glInitNames**

NAME
glInitNames — initialize the name stack

C SPECIFICATION
void glInitNames( void )

DESCRIPTION
The name stack is used during selection mode to allow sets of rendering commands to be uniquely identified. It consists of an ordered set of unsigned integers. glInitNames causes the name stack to be initialized to its default empty state.

The name stack is always empty while the render mode is not GL_SELECT. Calls to glInitNames while the render mode is not GL_SELECT are ignored.

ERRORS
GL_INVALID_OPERATION is generated if glInitNames is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_NAME_STACK_DEPTH

SEE ALSO
"glLoadName", "glPushName", "glRenderMode", "glSelectBuffer"
**glIsEnabled**

**NAME**
glIsEnabled — test whether a capability is enabled

**C SPECIFICATION**

```c
GLboolean glIsEnabled(GLenum cap);
```

**PARAMETERS**

- `cap` Specifies a symbolic constant indicating a GL capability.

**DESCRIPTION**

`glIsEnabled` returns `GL_TRUE` if `cap` is an enabled capability and returns `GL_FALSE` otherwise.

The following capabilities are accepted for `cap`:

- `GL_ALPHA_TEST` See "glAlphaFunc".
- `GL_AUTO_NORMAL` See "glEvalCoord".
- `GL_BLEND` See "glBlendFunc".
- `GL_CLIP_PLANE` See "glClipPlane".
- `GL_COLOR_MATERIAL` See "glColorMaterial".
- `GL_CULL_FACE` See "glCullFace".
- `GL_DEPTH_TEST` See "glDepthFunc" and "glDepthRange".
- `GL_DITHER` See "glEnable".
- `GL_FOG` See "glFog".
- `GL_LIGHT` See "glLightModel" and "glLight".
- `GL_LIGHTING` See "glLightModel", "glLightModel", and "glLight".
- `GL_LINE_SMOOTH` See "glLineStipple".
- `GL_LOGIC_OP` See "glLogicOp".
- `GL_MAP1_COLOR_4` See "glMap1".
- `GL_MAP1_INDEX` See "glMap1".
- `GL_MAP1_NORMAL` See "glMap1".
- `GL_MAP1_TEXTURE_COORD_1` See "glMap1".
- `GL_MAP1_TEXTURE_COORD_2` See "glMap1".
- `GL_MAP1_TEXTURE_COORD_3` See "glMap1".
- `GL_MAP1_TEXTURE_COORD_4` See "glMap1".
- `GL_MAP2_COLOR_4` See "glMap2".
- `GL_MAP2_INDEX` See "glMap2".
- `GL_MAP2_NORMAL` See "glMap2".
- `GL_MAP2_TEXTURE_COORD_1` See "glMap2".
- `GL_MAP2_TEXTURE_COORD_2` See "glMap2".
- `GL_MAP2_TEXTURE_COORD_3` See "glMap2".
- `GL_MAP2_TEXTURE_COORD_4` See "glMap2".
- `GL_MAP2_VERTEX_3` See "glMap2".
- `GL_MAP2_VERTEX_4` See "glMap2".
- `GL_NORMALIZE` See "glNormal".
- `GL_POINT_SMOOTH` See "glPointSize".
- `GL_POLYGON_SMOOTH` See "glPolygonMode".
- `GL_POLYGON_STIPPLE` See "glPolygonStipple".

**NOTES**

If an error is generated, glIsEnabled returns zero.

**ERRORS**

- `GL_INVALID_ENUM` is generated if `cap` is not an accepted value.
- `GL_INVALID_OPERATION` is generated if glIsEnabled is called between a call to glBegin and the corresponding call to glEnd.

**SEE ALSO**

- "glEnable"

**glIsList**

**NAME**

`glIsList` — test for display-list existence

**C SPECIFICATION**

```c
GLboolean glIsList(GLuint list);
```

**PARAMETERS**

- `list` Specifies a potential display-list name.

**DESCRIPTION**

`glIsList` returns `GL_TRUE` if list is the name of a display list and returns `GL_FALSE` otherwise.

**ERRORS**

- `GL_INVALID_OPERATION` is generated if `glIsList` is called between a call to glBegin and the corresponding call to glEnd.

**SEE ALSO**

- "glCallList", "glCallLists", "glDeleteLists", "glGenLists", "glNewList"
GL_DIFFUSE

params contains four integer or floating-point values that specify the diffuse RGBA intensity of the light. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to -1.0. Floating-point values are mapped directly. Neither integer nor floating-point values are clamped. The default diffuse intensity is (0.0, 0.0, 0.0, 1.0) for all lights other than light zero. The default diffuse intensity of light zero is (1.0, 1.0, 1.0, 1.0).

GL_SPECULAR

params contains four integer or floating-point values that specify the specular RGBA intensity of the light. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to -1.0. Floating-point values are mapped directly. Neither integer nor floating-point values are clamped. The default specular intensity of light zero is (1.0, 1.0, 1.0, 1.0).

GL_POSITION

params contains four integer or floating-point values that specify the position of the light in homogeneous object coordinates. Both integer and floating-point values are mapped directly. Neither integer nor floating-point values are clamped. The position is transformed by the modelview matrix when glLight is called (just as it were a normal), and it is stored in eye coordinates. It is significant only when w is 0.0, the light is treated as a directional source. Diffuse and specular lighting calculations take the light's direction, but not its actual position, into account, and attenuation is disabled. Otherwise, diffuse and specular lighting calculations are based on the actual location of the light in eye coordinates, and attenuation is enabled. The default position is (0, 0, 1, 0); thus, the default light source is directional, parallel to, and in the direction of the -z axis.

GL_SPOT_DIRECTION

params contains three integer or floating-point values that specify the direction of the light in homogeneous object coordinates. Both integer and floating-point values are mapped directly. Neither integer nor floating-point values are clamped. The position is transformed by the inverse of the modelview matrix when glLight is called (just as if it were a point), and it is stored in eye coordinates. If the w component of the position is 0.0, the light is treated as a directional source. Diffuse and specular lighting calculations take the light's direction, but not its actual position, into account, and attenuation is disabled. When lighting is enabled and disabled using glEnable and glDisable with argument GL_LIGHT i, the spot direction is stored in eye coordinates. It is significant only when GL_SPOT_CUTOFF is not 180, which it is by default. The default direction is (0.0, -1).
nonnegative values are accepted. If the light is positional, rather than directional, its intensity is attenuated by the reciprocal of the sum of: the constant factor, the linear factor times the distance between the light and the vertex being lighted, and the quadratic factor times the square of the same distance. The default attenuation factors are [1,0,0], resulting in no attenuation.

NOTES
It is always the case that GL_LIGHT0 = GL_LIGHT0 + i.

ERRORS
GL_INVALID_ENUM is generated if either light or pname is not an accepted value.
GL_INVALID_VALUE is generated if a spot exponent value is specified outside the range [0,128], or if spot cutoff is specified outside the range [0,90] (except for the special value 180), or if a negative attenuation factor is specified.
GL_INVALID_OPERATION is generated if glLight is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
.glGetLight .glIsEnabled with argument GL_LIGHTING

SEE ALSO
"glColorMaterial", "glLightModel", "glMaterial"

.glLightModel

NAME
.glLightModelf, .glLightModeli, .glLightModelfv, .glLightModeliv — set the lighting model parameters

C SPECIFICATION
void .glLightModelf ( GLenumpname, GLfloatparam )
void .glLightModeli ( GLenumpname, GLintparam )

PARAMETERS
pname Specifies a single−valued lighting model parameter.
param Specifies the value that param will be set to.

C SPECIFICATION
void .glLightModelfv ( GLenumpname, const GLfloat*params )
void .glLightModeliv ( GLenumpname, const GLint*params )

PARAMETERS
pname Specifies a lighting model parameter. GL_LIGHT_MODEL_AMBIENT, GL_LIGHT_MODEL_LOCAL_VIEWER, and GL_LIGHT_MODEL_TWO_SIDE are accepted.
params Specifies a pointer to the value or values that params will be set to.

DESCRIPTION
.glLightModel sets the lighting model parameter. pname names a parameter and params gives the new value. There are three lighting model parameters:

GL_LIGHT_MODEL_AMBIENT params contains four integer or floating−point values that specify the ambient RGBA intensity of the entire scene. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to −1.0. Floating−point values are mapped directly. Neither integer nor floating−point values are clamped. The default ambient scene intensity is (0.2, 0.2, 0.2, 1.0).

GL_LIGHT_MODEL_LOCAL_VIEWER params is a single integer or floating−point value that specifies how specular reflection angles are computed. If params is 0 (or 0.0), specular reflection angles take the view direction to be parallel to and in the direction of the −z axis, regardless of the location of the vertex in eye coordinates. Otherwise specular reflections are computed from the origin of the eye coordinate system. The default is 0.

GL_LIGHT_MODEL_TWO_SIDE params is a single integer or floating−point value that specifies whether one− or two−sided lighting calculations are done for polygons. It has no effect on the lighting calculations for points, lines, or bitmaps. If params is 0 (or 0.0), one−sided lighting is specified, and only the front material parameters are used in the lighting equation. Otherwise, two−sided lighting is specified. In this case, vertices of back−facing polygons are lighted using the back material parameters, and have their normals reversed before the lighting equation is evaluated. Vertices of front−facing polygons are always lighted using the front material parameters, with no change to their normals. The default is 0.

In RGBA mode, the lighted color of a vertex is the sum of the material emission intensity, the product of the material ambient reflectance and the lighting model full−scene ambient intensity, and the contribution of each enabled light source. Each light source contributes the sum of three terms: ambient, diffuse, and specular. The ambient light source contribution is the product of the material ambient reflectance and the light's ambient intensity. The diffuse light source contribution is the product of the material specular reflectance, the light's specular intensity, and the dot product of the normalized vertex−to−eye and vertex−to−light vectors, raised to the power of the shininess of the material. All three light source contributions are attenuated equally based on the distance from the vertex to the light source and on light source direction, spread exponent, and spread cutoff angle. All dot products are replaced with zero if they evaluate to a negative value.

The alpha component of the resulting lighted color is set to the alpha value of the material diffuse reflectance.

In color index mode, the value of the lighted index of a vertex ranges from the ambient to the specular values passed to .glMaterial using GL_COLOR_INDEXES. Diffuse and specular coefficients, computed with a (.30, .59, .11) weighting of the lights' colors, the shininess of the material, and the same reflection and attenuation equations as in the RGBA case, determine how much above ambient the resulting index is.
**ERRORS**

GL_INVALID_ENUM is generated if pname is not an accepted value.

GL_INVALID_OPERATION is generated if glLightModel is called between a call to glBegin and the corresponding call to glEnd.

**ASSOCIATED GETS**

- glGet with argument GL_LIGHT_MODEL_AMBIENT
- glGet with argument GL_LIGHT_MODEL_LOCAL_VIEWER
- glGet with argument GL_LIGHT_MODEL_TWO_SIDE
- glEnable with argument GL_LIGHTING

**SEE ALSO**

"glLight", "glMaterial"

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**NAME**

glLineStipple — specify the line stipple pattern

**C SPECIFICATION**

```c
void glLineStipple(GLint factor, GLushort pattern);
```

**PARAMETERS**

- `factor` Specifies a multiplier for each bit in the line stipple pattern. If factor is 3, for example, each bit in the pattern will be used three times before the next bit in the pattern is used. factor is clamped to the range [1, 255] and defaults to one.
- `pattern` Specifies a 16-bit integer whose bit pattern determines which fragments of a line will be drawn when the line is rasterized. Bit zero is used first, and the default pattern is all ones.

**DESCRIPTION**

Line stippling masks out certain fragments produced by rasterization; those fragments will not be drawn. The masking is achieved by using three parameters: the 16-bit line stipple pattern pattern, the repeat count factor, and an integer stipple counter s.

Counter s is reset to zero whenever glBegin is called, and before each line segment of a glBegin/glEnd sequence is generated. It is incremented after each fragment of a unit width aliased line segment is generated, or after each i fragments of an i width line segment are generated. The fragments associated with count s are masked out if pattern bit (s factor) mod 16 is zero, otherwise these fragments are sent to the frame buffer. Bit zero of pattern is the least significant bit.

Aliased lines are treated as a sequence of 1 × width rectangles for purposes of stippling. Rectangle s is rasterized or not based on the fragment rule described for aliased lines, counting rectangles rather than groups of fragments.

Line stippling is enabled or disabled using glEnable and glDisable with argument GL_LINE_STIPPLE. When enabled, the line stipple pattern is applied as described above. When disabled, it is as if the pattern were all ones. Initially, line stippling is disabled.

**ERRORS**

GL_INVALID_OPERATION is generated if glLineStipple is called between a call to glBegin and the corresponding call to glEnd.

**ASSOCIATED GETS**

- glGet with argument GL_LINE_STIPPLE_PATTERN
- glGet with argument GL_LINE_STIPPLE_REPEAT
- glEnable with argument GL_LINE_STIPPLE

**SEE ALSO**

"glLineWidth", "glPolygonStipple"

--

**NAME**

glLineWidth — specify the width of rasterized lines

**C SPECIFICATION**

```c
void glLineWidth(GLfloat width);
```

**PARAMETERS**

- `width` Specifies the width of rasterized lines. The default is 1.0.

**DESCRIPTION**

glLineWidth specifies the rasterized width of both aliased and antialiased lines. Using a line width other than 1.0 has different effects, depending on whether line antialiasing is enabled. Line antialiasing is controlled by calling glEnable and glDisable with argument GL_LINE_SMOOTH.

If line antialiasing is disabled, the actual width is determined by rounding the supplied width to the nearest integer. If the rounding results in the value 0, it is as if the line width were 1.0. If \( |\Delta x| \geq |\Delta y| \), \( i \) pixels are filled in each column that is rasterized, where \( i \) is the rounded value of width. Otherwise, \( i \) pixels are filled in each row that is rasterized.

If antialiasing is enabled, line rasterization produces a fragment for each pixel square that intersects the region lying within the rectangle having width equal to the current line width, length equal to the actual length of the line, and centered on the mathematical line segment. The coverage value for each fragment is the window coordinate area of the intersection of the rectangular region with the corresponding pixel square. This value is saved and used in the final rasterization step.

Not all widths can be supported when line antialiasing is enabled. If an unsupported width is requested, the nearest supported width is used. Only width 1.0 is guaranteed to be supported; others depend on the implementation. The range of supported widths and the size difference between supported widths within the range can be queried by calling glGet with arguments GL_LINE_WIDTH_RANGE and GL_LINE_WIDTH_GRANULARITY.
NOTES

The line width specified by `glLineWidth` is always returned when `GL_LINE_WIDTH` is queried. Clamping and rounding for aliased and antialiased lines have no effect on the specified value. Non-antialiased line width may be clamped to an implementation-dependent maximum. Although this maximum cannot be queried, it must be no less than the maximum value for antialiased lines, rounded to the nearest integer value.

ERRORS

`GL_INVALID_VALUE` is generated if width is less than or equal to zero.

`GL_INVALID_OPERATION` is generated if `glLineWidth` is called between a call to `glBegin` and the corresponding call to `glEnd`.

ASSOCIATED GETS

`glGet` with argument `GL_LINE_WIDTH`
`glGet` with argument `GL_LINE_WIDTH_RANGE`
`glGet` with argument `GL_LINE_WIDTH_GRANULARITY`
`glIsEnabled` with argument `GL_LINE_SMOOTH`

SEE ALSO

`'glEnable'`

`glListBase`

NAME

`glListBase` – set the display-list base for `glCallLists`

C SPECIFICATION

```c
void glListBase ( GLuint base )
```

PARAMETERS

base Specifies an integer offset that will be added to `glCallLists` offsets to generate display-list names. Initial value is zero.

DESCRIPTION

`glCallLists` specifies an array of offsets. Display-list names are generated by adding base to each offset. Names that reference valid display lists are executed; the others are ignored.

ERRORS

`GL_INVALID_OPERATION` is generated if `glListBase` is called between a call to `glBegin` and the corresponding call to `glEnd`.

ASSOCIATED GETS

`glGet` with argument `GL_LIST_BASE`

SEE ALSO

`'glCallLists'`

`glLoadIdentity`

NAME

`glLoadIdentity` – replace the current matrix with the identity matrix

C SPECIFICATION

```c
void glLoadIdentity ( void )
```

DESCRIPTION

`glLoadIdentity` replaces the current matrix with the identity matrix. It is semantically equivalent to calling `glLoadMatrix` with the identity matrix but in some cases it is more efficient.

ERRORS

`GL_INVALID_OPERATION` is generated if `glLoadIdentity` is called between a call to `glBegin` and the corresponding call to `glEnd`.

ASSOCIATED GETS

`glGet` with argument `GL_MATRIX_MODE`
`glGet` with argument `GL_MODELVIEW MATRIX`
`glGet` with argument `GL_PROJECTION MATRIX`
`glGet` with argument `GL_TEXTURE_MATRIX`

SEE ALSO

`'glLoadMatrix', 'glMatrixMode', 'glMultMatrix', 'glPushMatrix'`

`glLoadMatrix`
NAME

glLoadMatrixd, glLoadMatrixf — replace the current matrix with an arbitrary matrix

C SPECIFICATION

void glLoadMatrixd( const GLdouble *m )
void glLoadMatrixf( const GLfloat *m )

PARAMETERS

m Specifies a pointer to a 4\times4 matrix stored in column-major order as sixteen consecutive values.

DESCRIPTION

glLoadMatrix replaces the current matrix with the one specified in m. The current matrix is the projection matrix, modelview matrix, or texture matrix, determined by the current matrix mode (see "glMatrixMode").

\( m \) points to a 4\times4 matrix of single- or double-precision floating-point values stored in column-major order. That is, the matrix is stored as follows:

\[
\begin{pmatrix}
  a_0 & a_4 & a_8 & a_{12} \\
  a_1 & a_5 & a_9 & a_{13} \\
  a_2 & a_6 & a_{10} & a_{14} \\
  a_3 & a_7 & a_{11} & a_{15}
\end{pmatrix}
\]

ERRORS

GL_INVALID_OPERATION is generated if glLoadMatrix is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

glGet with argument GL_MATRIX_MODE
glGet with argument GL_MODELVIEW_MATRIX
glGet with argument GL_PROJECTION_MATRIX

SEE ALSO

"glLoadIdentity", "glMatrixMode", "glMultMatrix"
DESCRIPTION

eglLogOp specifies a logical operation that, when enabled, is applied between the incoming color index and the color index at the corresponding location in the frame buffer. The logical operation is enabled or disabled with glEnable and glDisable using the symbolic constant GL_LOGIC_OP.

opcode is a symbolic constant chosen from the list below. In the explanation of the logical operations, s represents the incoming color index and d represents the index in the frame buffer. Standard C-language operators are used. As these bitwise operators suggest, the logical operation is applied independently to each bit pair of the source and destination indices.

<table>
<thead>
<tr>
<th>opcode</th>
<th>resulting value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL_CLEAR</td>
<td>0</td>
</tr>
<tr>
<td>GL_SET</td>
<td>1</td>
</tr>
<tr>
<td>GL_COPY</td>
<td>s</td>
</tr>
<tr>
<td>GL_COPY_INVERTED</td>
<td>s</td>
</tr>
<tr>
<td>GL_NOOP</td>
<td>d</td>
</tr>
<tr>
<td>GL_INVERT</td>
<td>s</td>
</tr>
<tr>
<td>GL_AND</td>
<td>s &amp; d</td>
</tr>
<tr>
<td>GL_NAND</td>
<td>(s &amp; d)</td>
</tr>
<tr>
<td>GL_OR</td>
<td>s</td>
</tr>
<tr>
<td>GL_NOR</td>
<td>s</td>
</tr>
<tr>
<td>GL_XOR</td>
<td>s ^ d</td>
</tr>
<tr>
<td>GL_AND_REVERSE</td>
<td>s</td>
</tr>
<tr>
<td>GL_AND_INVERTED</td>
<td>s</td>
</tr>
<tr>
<td>GL_OR_REVERSE</td>
<td>s</td>
</tr>
<tr>
<td>GL_OR_INVERTED</td>
<td>s</td>
</tr>
</tbody>
</table>

NOTES

Logical pixel operations are not applied to RGBA color buffers.

When more than one color index buffer is enabled for drawing, logical operations are done separately for each enabled buffer, using for the destination index the contents of that buffer (see "glDrawBuffer").

opcode must be one of the sixteen accepted values. Other values result in an error.

ERRORS

GL_INVALID_ENUM is generated if opcode is not an accepted value.

GL_INVALID_OPERATION is generated if eglLogOp is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

eglGet with argument GL_LOGIC_OP_MODE
eglIsEnabled with argument GL_LOGIC_OP

SEE ALSO

"glAlphaFunc", "glBlendFunc", "glDrawBuffer", "glEnable", "glStencilOp"

NAME

gMap1d, glMap1f - define a one-dimensional evaluator

C SPECIFICATION

void glMap1d (GLenum target, GLdouble u1, GLdouble u2, GLint stride, GLint order, const GLdouble *points )

void glMap1f (GLenum target, GLfloat u1, GLfloat u2, GLint stride, GLint order, const GLfloat *points )

PARAMETERS

<table>
<thead>
<tr>
<th>parameter</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>target</td>
<td>Specifies the kind of values that are generated by the evaluator. Symbolic constants GL_MAP1_VERTEX_3, GL_MAP1_VERTEX_4, GL_MAP1_INDEX, GL_MAP1_COLOR_4, GL_MAP1_NORMAL, GL_MAP1_TEXTURE_COORD_1, GL_MAP1_TEXTURE_COORD_2, GL_MAP1_TEXTURE_COORD_3, and GL_MAP1_TEXTURE_COORD_4 are accepted.</td>
</tr>
<tr>
<td>u1, u2</td>
<td>Specify a linear mapping of u, as presented to glEvalCoord1, to ( u^\prime ), the variable that is evaluated by the equations specified by this command.</td>
</tr>
<tr>
<td>stride</td>
<td>Specifies the number of floats or doubles between the beginning of one control point and the beginning of the next one in the data structure referenced in points. This allows control points to be embedded in arbitrary data structures. The only constraint is that the values for a particular control point must occupy contiguous memory locations.</td>
</tr>
<tr>
<td>order</td>
<td>Specifies the number of control points. Must be positive.</td>
</tr>
<tr>
<td>points</td>
<td>Specifies a pointer to the array of control points.</td>
</tr>
</tbody>
</table>

DESCRIPTION

Evaluators provide a way to use polynomial or rational polynomial mapping to produce vertices, normals, texture coordinates, and colors. The values produced by an evaluator are sent to further stages of GL processing just as if they had been presented using glVertex, glNormal, glTexCoord, and glColor commands, except that the generated values do not update the current normal, texture coordinates, or color.

All polynomial or rational polynomial splines of any degree (up to the maximum degree supported by the GL implementation) can be described using evaluators. These include almost all splines used in computer graphics, including B-splines, Bezier curves, Hermite splines, and so on.

Evaluators define curves based on Bernstein polynomials. Define \( p (u) \) as

\[
p (u) = \sum_{i=0}^n B^2_i(u) R_i
\]

where \( R_i \) is a control point and \( B^2_i (u^\prime) \) is the ith Bernstein polynomial of degree n (order = n + 1):
Recall that `glMap1` is used to define the basis and to specify what kind of values are produced. Once defined, a map can be enabled and disabled by calling `glEnable` and `glDisable` with the map name, one of the nine predefined values for `target` described below.

- `glEvalCoord1` evaluates the one-dimensional maps that are enabled. When `glEvalCoord1` presents a value \( u \), the Bernstein functions are evaluated using \( u \), where

\[
B_i^n(\hat{u}) = \begin{bmatrix} n! \end{bmatrix} \hat{u}^i (1 - \hat{u})^{n - i}
\]

Recall that

\[
0^n \equiv 1 \quad \text{and} \quad \begin{bmatrix} n \end{bmatrix}_0 \equiv 1
\]

`glMap1` is used to define the basis and to specify what kind of values are produced. Once defined, a map can be enabled and disabled by calling `glEnable` and `glDisable` with the map name, one of the nine predefined values for `target` described below. `glEvalCoord1` evaluates the one-dimensional maps that are enabled. When `glEvalCoord1` presents a value \( u \), the Bernstein functions are evaluated using \( u \), where

\[
\hat{u} = \frac{u - u_1}{u_2 - u_1}
\]

`target` is a symbolic constant that indicates what kind of control points are provided in `points`, and what output is generated when the map is evaluated. It can assume one of nine predefined values:

- **GL_MAP1_VERTEX_3**: Each control point is three floating-point values representing \( x \), \( y \), and \( z \). Internal `glVertex3` commands are generated when the map is evaluated.
- **GL_MAP1_VERTEX_4**: Each control point is four floating-point values representing \( x \), \( y \), \( z \), and \( w \). Internal `glVertex4` commands are generated when the map is evaluated.
- **GL_MAP1_INDEX**: Each control point is a single floating-point value representing a color index. Internal `glIndex` commands are generated when the map is evaluated. The current index is not updated with the value of these `glIndex` commands, however.
- **GL_MAP1_COLOR_4**: Each control point is four floating-point values representing red, green, blue, and alpha. Internal `glColor4` commands are generated when the map is evaluated. The current color is not updated with the value of these `glColor4` commands, however.
- **GL_MAP1_NORMAL**: Each control point is three floating-point values representing \( x \), \( y \), and \( z \) the map is evaluated. The current normal is not updated with the value of these `glNormal` commands, however.
- **GL_MAP1_TEXTURE_COORD_1**: Each control point is a single floating-point value representing a texture coordinate. Internal `glTexCoord1` commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these `glTexCoord` commands, however.
- **GL_MAP1_TEXTURE_COORD_2**: Each control point is two floating-point values representing \( s \) and \( t \) texture coordinates. Internal `glTexCoord2` commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these `glTexCoord` commands, however.
- **GL_MAP1_TEXTURE_COORD_3**: Each control point is three floating-point values representing \( s \), \( t \), and \( r \) texture coordinates. Internal `glTexCoord3` commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these `glTexCoord` commands, however.
- **GL_MAP1_TEXTURE_COORD_4**: Each control point is four floating-point values representing \( s \), \( t \), \( r \), and \( q \) texture coordinates. Internal `glTexCoord4` commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these `glTexCoord` commands, however.

`stride`, `order`, and `points` define the array addressing for accessing the control points. `points` is the location of the first control point, which occupies one, two, three, or four contiguous memory locations, depending on which map is being defined. `order` is the number of control points in the array. `stride` tells how many float or double locations to advance the internal memory pointer to reach the next control point.

**NOTES**

As is the case with all `GL` commands that accept pointers to data, it is as if the contents of `points` were copied by `glMap1` before it returned. Changes to the contents of `points` have no effect after `glMap1` is called.

**ERRORS**

- `GL_INVALID_ENUM` is generated if `target` is not an accepted value.
- `GL_INVALID_VALUE` is generated if \( u_1 \) is equal to \( u_2 \).
- `GL_INVALID_VALUE` is generated if `stride` is less than the number of values in a control point.
- `GL_INVALID_VALUE` is generated if `order` is less than one or greater than `GL_MAX_EVAL_ORDER`.
- `GL_INVALID_OPERATION` is generated if `glMap1` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGetMap` with argument `GL_MAP1_VERTEX_3`
- `glGetMap` with argument `GL_MAP1_VERTEX_4`
- `glGetMap` with argument `GL_MAP1_INDEX`
- `glGetMap` with argument `GL_MAP1_COLOR_4`
glIsEnabled with argument GL_MAP1_NORMAL

glIsEnabled with argument GL_MAP1_TEXTURE_COORD_1

glIsEnabled with argument GL_MAP1_TEXTURE_COORD_2

glIsEnabled with argument GL_MAP1_TEXTURE_COORD_3

glIsEnabled with argument GL_MAP1_TEXTURE_COORD_4

SEE ALSO

glMap2

NAME

glMap2d, glMap2f—define a two−dimensional evaluator

C SPECIFICATION

void glMap2d ( GLenum target, GLdouble u1, GLdouble u2, GLint ustride, GLint uorder, GLdouble v1, GLdouble v2, GLint vstride, GLint vorder, const GLdouble *points )

void glMap2f ( GLenum target, GLfloat u1, GLfloat u2, GLint ustride, GLint uorder, GLfloat v1, GLfloat v2, GLint vstride, GLint vorder, const GLfloat *points )

PARAMETERS

target Specifies the kind of values that are generated by the evaluator. Symbolic constants

GL_MAP2_VERTEX_3, GL_MAP2_VERTEX_4, GL_MAP2_INDEX, GL_MAP2_COLOR_4, GL_MAP2_NORMAL, GL_MAP2_TEXTURE_COORD_1, GL_MAP2_TEXTURE_COORD_2, GL_MAP2_TEXTURE_COORD_3, and

GL_MAP2_TEXTURE_COORD_4 are accepted.

u1, u2 Specify a linear mapping of u, as presented to glEvalCoord2, to u^, one of the two variables that is evaluated by the equations specified by this command.

ustride Specifies the number of floats or doubles between the beginning of control point Rij and the beginning of control point R ( i+1) j , where i and j are the u and v control point indices, respectively. This allows control points to be embedded in arbitrary data structures. The only constraint is that the values for a particular control point must occupy contiguous memory locations.

uorder Specifies the dimension of the control point array in the u axis. Must be positive.

v1, v2 Specify a linear mapping of v, as presented to glEvalCoord2, to v^, one of the two variables that is evaluated by the equations specified by this command.

vstride Specifies the number of floats or doubles between the beginning of control point Rij and the beginning of control point R i ( j+1) , where i and j are the u and v control point indices, respectively. This allows control points to be embedded in arbitrary data structures. The only constraint is that the values for a particular control point must occupy contiguous memory locations.

vorder Specifies the dimension of the control point array in the v axis. Must be positive.

points Specifies a pointer to the array of control points.

DESCRIPTION

Evaluators provide a way to use polynomial or rational polynomial mapping to produce vertices, normals, texture coordinates, and colors. The values produced by an evaluator are sent on to further stages of GL processing just as if they had been presented using glVertex, glNormal, glTexCoord, and glColor commands, except that the generated values do not update the current normal, texture coordinates, or color.

All polynomial or rational polynomial splines of any degree (up to the maximum degree supported by the GL implementation) can be described using evaluators. These include almost all surfaces used in computer graphics, including B−spline surfaces, NURBS surfaces, Bezier surfaces, and so on.

Evaluators define surfaces based on bivariate Bernstein polynomials. Define

\[ p (\hat{u}, \hat{v}) \]

as

\[ p (\hat{u}, \hat{v}) = \sum_{i=0}^{n} \sum_{j=0}^{m} B^{n}_{i} (\hat{u}) B^{m}_{j} (\hat{v}) R_{ij} \]

where Rij is a control point, B^{n}_{i} (u^) is the i th Bernstein polynomial of degree n (uorder = n + 1) and B^{m}_{j} (v^) is the j th Bernstein polynomial of degree m (vorder = m + 1)

\[ B^{n}_{i} (\hat{u}) = \binom{n}{i} \hat{u}^{i} (1 - \hat{u})^{n-i} \]

and \[ B^{m}_{j} (\hat{v}) = \binom{m}{j} \hat{v}^{j} (1 - \hat{v})^{m-j} \]

Recall that
A bivariate Bernstein polynomial is evaluated using \( u^i \) and \( v^j \), where

\[
\hat{u} = \frac{u - u_1}{u_2 - u_1}, \quad \hat{v} = \frac{v - v_1}{v_2 - v_1}
\]

The internal \( \text{glTexCoord1} \) commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

The internal \( \text{glTexCoord2} \) commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

The internal \( \text{glTexCoord3} \) commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

The internal \( \text{glTexCoord4} \) commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

The current index is not updated with the value of these \( \text{glIndex} \) commands, however.

The current color is not updated with the value of these \( \text{glColor} \) commands, however.

The current normal is not updated with the value of these \( \text{glNormal} \) commands, however.

The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

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The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

Each control point is a single floating-point value representing a color index. Internal \( \text{glIndex} \) commands are generated when the map is evaluated. The current index is not updated with the value of these \( \text{glIndex} \) commands, however.

Each control point is four floating-point values representing the \( s, t, r, \) and \( q \) texture coordinates. Internal \( \text{glTexCoord4} \) commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

Each control point is four floating-point values representing the \( s, t, r, \) and \( q \) texture coordinates. Internal \( \text{glTexCoord4} \) commands are generated when the map is evaluated. The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

Each control point is four floating-point values representing red, green, blue, and alpha. Internal \( \text{glColor4} \) commands are generated when the map is evaluated. The current color is not updated with the value of these \( \text{glColor} \) commands, however.

Each control point is a single floating-point value representing a color index. Internal \( \text{glIndex} \) commands are generated when the map is evaluated. The current index is not updated with the value of these \( \text{glIndex} \) commands, however.

Each control point is four floating-point values representing \( x, y, z, \) and \( w \). Internal \( \text{glVertex4} \) commands are generated when the map is evaluated. The current vertex is not updated with the value of these \( \text{glVertex} \) commands, however.

Each control point is a single floating-point value representing a color index. Internal \( \text{glIndex} \) commands are generated when the map is evaluated. The current index is not updated with the value of these \( \text{glIndex} \) commands, however.

Each control point is four floating-point values representing \( x, y, z, \) and \( w \). Internal \( \text{glVertex4} \) commands are generated when the map is evaluated. The current vertex is not updated with the value of these \( \text{glVertex} \) commands, however.

Each control point is three floating-point values representing \( x, y, z, \) and \( w \). Internal \( \text{glVertex3} \) commands are generated when the map is evaluated. The current vertex is not updated with the value of these \( \text{glVertex} \) commands, however.

Each control point is three floating-point values representing \( x, y, z, \) and \( w \). Internal \( \text{glVertex3} \) commands are generated when the map is evaluated. The current vertex is not updated with the value of these \( \text{glVertex} \) commands, however.

The current index is not updated with the value of these \( \text{glIndex} \) commands, however.

The current color is not updated with the value of these \( \text{glColor} \) commands, however.

The current normal is not updated with the value of these \( \text{glNormal} \) commands, however.

The current normal is not updated with the value of these \( \text{glNormal} \) commands, however.

The current texture coordinates are not updated with the value of these \( \text{glTexCoord} \) commands, however.

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The mappings specified by `glMapGrid` are used identically by `glEvalMesh` and `glEvalPoint`.

**ERRORS**

- `GL_INVALID_VALUE` is generated if either `un` or `vn` is not positive.
- `GL_INVALID_OPERATION` is generated if `glMapGrid` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGet` with argument `GL_MAP1_GRID_DOMAIN` or `GL_MAP2_GRID_DOMAIN`.
- `glGet` with argument `GL_MAP1_GRID_SEGMENTS` or `GL_MAP2_GRID_SEGMENTS`.

**SEE ALSO**

- `glMap1` and `glMap2`.
- The C specification of `glMapGrid`, `glEvalCoord`, `glEvalMesh`, `glEvalPoint`, `glMap1`, `glMapGrid2`, and `glVertex`.

---

**glMapGrid**

**NAME**

- `glMapGrid1d`, `glMapGrid2d`, `glMapGrid2f`, `glMapGrid3f` — define a one- or two-dimensional mesh

**C SPECIFICATION**

```c
void glMapGrid1d ( GLint un, GLdouble u1, GLdouble u2 )
void glMapGrid1f ( GLint un, GLfloat u1, GLfloat u2 )
void glMapGrid2d ( GLint un, GLdouble u1, GLdouble u2, GLint vn, GLdouble v1, GLdouble v2 )
void glMapGrid2f ( GLint un, GLfloat u1, GLfloat u2, GLint vn, GLfloat v1, GLfloat v2 )
```

**PARAMETERS**

- `un`: Specifies the number of partitions in the grid range interval [u1, u2]. Must be positive.
- `u1`, `u2`: Specify the mappings for integer grid domain values i=0 and i=un.
- `vn`: Specifies the number of partitions in the grid range interval [v1, v2] (`glMapGrid2` only).
- `v1`, `v2`: Specify the mappings for integer grid domain values j=0 and j=vn (`glMapGrid2` only).

**DESCRIPTION**

- `glMapGrid1` and `glMapGrid2` specify the linear grid mappings between the integer domain of a one- or two-dimensional grid, whose range is the domain of the evaluation maps specified by `glMap1` and `glMap2`.
- The integer grid coordinates, to the u (or v) floating-point evaluation map coordinates. See `glMap1` and `glMap2` for details of how u and v coordinates are evaluated.

** SEE ALSO**

- `glMap1` and `glMap2`.
- The C specification of `glMapGrid`, `glEvalCoord`, `glEvalMesh`, `glEvalPoint`, `glMap1`, `glMap2`. 

---

**glMaterial**

**NAME**

- `glMaterialf`, `glMateriali`, `glMaterialfv`, `glMaterialiv` — specify material parameters for the lighting model

**C SPECIFICATION**

```c
void glMaterialf ( GLenum face, GLenum pname, GLfloat param )
void glMaterialf ( GLenum face, GLenum pname, GLint param )
```

**PARAMETERS**

- `face`: Specifies which face or faces are being updated. Must be one of `GL_FRONT`, `GL_BACK`, or `GL_FRONT_AND_BACK`.
- `pname`: Specifies the single-valued material parameter of the face or faces that is being updated. Must be `GL_AMBIENT`, `GL_DIFFUSE`, `GL_SPECULAR`, `GL_EMISSION`, `GL_SHININESS`, `GL_AMBIENT_AND_DIFFUSE`, or `GL_COLOR_INDEXES`.
- `param`: Specifies the value that parameter `GL_SHININESS` will be set to.

**SEE ALSO**

- `glMapGrid`, `glEvalCoord`, `glEvalMesh`, `glEvalPoint`, `glMap1`, `glMap2`.
- The C specification of `glMapGrid`, `glEvalCoord`, `glEvalMesh`, `glEvalPoint`, `glMap1`, `glMap2`.
DESCRIPTION

`glMaterial` assigns values to material parameters. There are two matched sets of material parameters. One, the front-facing set, is used to shade points, lines, bitmaps, and all polygons (when two-sided lighting is disabled), or just front-facing polygons (when two-sided lighting is enabled). The other set, back-facing, is used to shade back-facing polygons only when two-sided lighting is enabled. The third parameter specifies which of several parameters in one or both sets will be modified. The third parameter specifies what value or values will be assigned to the specified parameter.

Material parameters are used in the lighting equation that is optionally applied to each vertex. The equation is discussed in the `glLightModel` reference page. The parameters that can be specified using `glMaterial`, and their interpretations by the lighting equation, are as follows:

**GL_AMBIENT**
Contains four integer or floating-point values that specify the ambient RGBA reflectance of the material. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to -1.0. The default ambient reflectance for both front- and back-facing materials is (0.2, 0.2, 0.2, 1.0).

**GL_DIFFUSE**
Contains four integer or floating-point values that specify the diffuse RGBA reflectance of the material. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to -1.0. The default diffuse reflectance for both front- and back-facing materials is (0.8, 0.8, 0.8, 1.0).

**GL_SPECULAR**
Contains four integer or floating-point values that specify the specular RGBA reflectance of the material. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to -1.0. The default specular reflectance for both front- and back-facing materials is (0.0, 0.0, 0.0, 1.0).

**GL_EMISSION**
Contains four integer or floating-point values that specify the RGBA emitted light intensity of the material. Integer values are mapped linearly such that the most positive representable value maps to 1.0, and the most negative representable value maps to -1.0. The default emission intensity for both front- and back-facing materials is (0.0, 0.0, 0.0, 1.0).

**GL_SHININESS**
Contains a single integer or floating-point value that specifies the RGB specular exponent of the material. Integer and floating-point values are mapped directly. Only values in the range [0, 128] are accepted. The default specular exponent for both front- and back-facing materials is 0.

**GL_AMBIENT_AND_DIFFUSE**
Equivalent to calling `glMaterial` twice with the same parameter values, once with `GL_AMBIENT` and once with `GL_DIFFUSE`.

**GL_COLOR_INDEXES**
Contains three integer or floating-point values specifying the color indices for ambient, diffuse, and specular lighting. These three values, and **GL_SHININESS**, are the only material values used by the color index mode lighting equation. Refer to the `glLightModel` reference page for a discussion of color index lighting.

NOTES

The material parameters can be updated at any time. In particular, `glMaterial` can be called between a call to `glBegin` and the corresponding call to `glEnd`. If only a single material parameter is to be changed per vertex, however, `glColorMaterial` is preferred over `glMaterial` (see "glColorMaterial").

ERRORS

GL_INVALID_ENUM is generated if either `face` or `pname` is not an accepted value.

GL_INVALID_VALUE is generated if a specular exponent outside the range [0,128] is specified.

ASSOCIATED GETS

`glGetMaterial`

SEE ALSO

"glColorMaterial", "glLight", "glLightModel"

`glMatrixMode`

NAME

`glMatrixMode` — specify which matrix is the current matrix

C SPECIFICATION

void `glMatrixMode` ( GLenum mode )

PARAMETERS

mode Specifies which matrix stack is the target for subsequent matrix operations. Three values are accepted: GL_MODELVIEW, GL_PROJECTION, and GL_TEXTURE.

DESCRIPTION

`glMatrixMode` sets the current matrix mode. mode can assume one of three values:

- **GL_MODELVIEW** Applies subsequent matrix operations to the modelview matrix stack.
- **GL_PROJECTION** Applies subsequent matrix operations to the projection matrix stack.
- **GL_TEXTURE** Applies subsequent matrix operations to the texture matrix stack.

ERRORS

GL_INVALID_ENUM is generated if mode is not an accepted value.

GL_INVALID_OPERATION is generated if `glMatrixMode` is called between a call to `glBegin` and the corresponding call to `glEnd`. 
ASSOCIATED GETS
 glGet with argument GL_MATRIX_MODE

SEE ALSO
 'glLoadMatrix', 'glMatrixMode', 'glPushMatrix'

**glMultMatrix**

**NAME**
glMultMatrixd, glMultMatrixf — multiply the current matrix by an arbitrary matrix

**C SPECIFICATION**
void glMultMatrixd (const GLdouble *m)
void glMultMatrixf (const GLfloat *m)

**PARAMETERS**
m Specifies a pointer to a 4×4 matrix stored in column-major order as sixteen consecutive values.

**DESCRIPTION**
glMultMatrix multiplies the current matrix with the one specified in m. That is, if M is the current matrix and T is the matrix passed to glMultMatrix, then M is replaced with MT.

The current matrix is the projection matrix, modelview matrix, or texture matrix, determined by the current matrix mode (see "glMatrixMode").

m points to a 4×4 matrix of single-or double-precision floating-point values stored in column-major order. That is, the matrix is stored as

\[
\begin{bmatrix}
    a_0 & a_4 & a_8 & a_{12} \\
    a_1 & a_5 & a_9 & a_{13} \\
    a_2 & a_6 & a_{10} & a_{14} \\
    a_3 & a_7 & a_{11} & a_{15} \\
\end{bmatrix}
\]

**ERRORS**

GL_INVALID_OPERATION is generated if glMultMatrix is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
 glGet with argument GL_MATRIX_MODE
 glGet with argument GL_MODELVIEW_MATRIX
 glGet with argument GL_PROJECTION_MATRIX
 glGet with argument GL_TEXTURE_MATRIX

SEE ALSO
 'glMatrixMode', 'glLoadIdentity', 'glLoadMatrix', 'glPushMatrix'

**glNewList**

**NAME**
glNewList, glEndList — create or replace a display list

**C SPECIFICATION**
void glNewList (GLuint list, GLenum mode)

**PARAMETERS**
list Specifies the display list name.
mode Specifies the compilation mode, which can be GL_COMPILE or GL_COMPILE_AND_EXECUTE.

**DESCRIPTION**
Display lists are groups of GL commands that have been stored for subsequent execution. The display lists are created with glNewList. All subsequent commands are placed in the display list, in the order issued, until glEndList is called.

glNewList has two arguments. The first argument, list, is a positive integer that becomes the unique name for the display list. Names can be created and reserved with glGenLists and tested for uniqueness with glIsList. The second argument, mode, is a symbolic constant that can assume one of two values:

GL_COMPILE Commands are merely compiled.
GL_COMPILE_AND_EXECUTE Commands are executed as they are compiled into the display list.

Certain commands are not compiled into the display list, but are executed immediately, regardless of the display-list mode. These commands are glList, glGenLists, glDeleteLists, glFeedbackBuffer, glSelectBuffer, glRenderMode, glReadPixels, glPixelStore, glFlush, glFinish, glEnable, and all of the glGet routines.

When glEndList is encountered, the display-list definition is completed by associating the list with the unique name list (specified in the glNewList command). If a display list with name list already exists, it is replaced only when glEndList is called.
glCallList and glCallLists can be entered into display lists. The commands in the display list or lists executed by glCallList or glCallLists are not included in the display list being created, even if the list creation mode is GL_COMPILE_AND_EXECUTE.

ERRORS

- GL_INVALID_VALUE is generated if list is zero.
- GL_INVALID_ENUM is generated if mode is not an accepted value.
- GL_INVALID_OPERATION is generated if glEndList is called without a preceding glNewList, or if glNewList is called while a display list is being defined.

ASSOCIATED GETS

glIsList

SEE ALSO

"glCallList", "glCallLists", "glDeleteLists", "glGenLists"

NAME

glNormal

C SPECIFICATION

void glNormal3b( GLbyte nx, GLbyte ny, GLbyte nz )
void glNormal3d( GLdouble nx, GLdouble ny, GLdouble nz )
void glNormal3f( GLfloat nx, GLfloat ny, GLfloat nz )
void glNormal3i( GLint nx, GLint ny, GLint nz )
void glNormal3s( GLshort nx, GLshort ny, GLshort nz )

void glNormal3bv( const GLbyte *v )
void glNormal3dv( const GLdouble *v )
void glNormal3fv( const GLfloat *v )
void glNormal3iv( const GLint *v )
void glNormal3sv( const GLshort *v )

C SPECIFICATION

void glNormal3b( GLbyte nx, GLbyte ny, GLbyte nz )
void glNormal3d( GLdouble nx, GLdouble ny, GLdouble nz )
void glNormal3f( GLfloat nx, GLfloat ny, GLfloat nz )
void glNormal3i( GLint nx, GLint ny, GLint nz )
void glNormal3s( GLshort nx, GLshort ny, GLshort nz )

void glNormal3bv( const GLbyte *v )
void glNormal3dv( const GLdouble *v )
void glNormal3fv( const GLfloat *v )
void glNormal3iv( const GLint *v )
void glNormal3sv( const GLshort *v )

void glNormal3b( GLbyte nx, GLbyte ny, GLbyte nz )
void glNormal3d( GLdouble nx, GLdouble ny, GLdouble nz )
void glNormal3f( GLfloat nx, GLfloat ny, GLfloat nz )
void glNormal3i( GLint nx, GLint ny, GLint nz )
void glNormal3s( GLshort nx, GLshort ny, GLshort nz )

void glNormal3bv( const GLbyte *v )
void glNormal3dv( const GLdouble *v )
void glNormal3fv( const GLfloat *v )
void glNormal3iv( const GLint *v )
void glNormal3sv( const GLshort *v )

PARAMETERS

- nx, ny, nz Specify the x, y, and z coordinates of the new current normal. The initial value of the current normal is (0,0,1).
- v Specifies a pointer to an array of three elements: the x, y, and z coordinates of the new current normal.

DESCRIPTION

The current normal is set to the given coordinates whenever glNormal is issued. Byte, short, or integer arguments are converted to floating-point format with a linear mapping that maps the most positive representable integer value to 1.0, and the most negative representable integer value to −1.0. Normals specified with glNormal need not have unit length. If normalization is enabled, then normals specified with glNormal are normalized after transformation. Normalization is controlled using glEnable and glDisable with the argument GL_NORMALIZE. By default, normalization is disabled.

ASSOCIATED GETS

glGet with argument GL_CURRENT_NORMAL

glIsEnable with argument GL_NORMALIZE

SEE ALSO

"glBegin", "glColor", "glIndex", "glTexCoord", "glVertex"

glOrtho

NAME

glOrtho

C SPECIFICATION

void glOrtho( GLdouble left, GLdouble right, GLdouble bottom, GLdouble top, GLdouble near, GLdouble far )

PARAMETERS

- left, right Specify the coordinates for the left and right vertical clipping planes.
- bottom, top Specify the coordinates for the bottom and top horizontal clipping planes.
- near, far Specify the distances to the nearer and farther depth clipping planes. These distances are negative if the plane is to be behind the viewer.

DESCRIPTION

glOrtho describes a perspective matrix that produces a parallel projection. (left, bottom, −near) and (right, top, −near) specify the points on the near clipping plane that are mapped to the lower left and upper right corners of the window, respectively, assuming that the eye is located at (0, 0, 0). −far specifies the location of the far clipping plane. Both near and far can be either positive or negative. The corresponding matrix is

\[
\begin{pmatrix}
\frac{2 \cdot \text{left}}{\text{right} - \text{left}} & \frac{-1}{\frac{\text{right} - \text{left}}{2 \cdot \text{near}}} & 0 & 0 \\
\frac{2 \cdot \text{bottom}}{\text{top} - \text{bottom}} & \frac{-1}{\frac{\text{top} - \text{bottom}}{2 \cdot \text{near}}} & 0 & 0 \\
0 & 0 & 1 & 0 \\
\frac{\text{far} - \text{near}}{\text{far} + \text{near}} & \frac{-2 \cdot \text{far}}{\text{far} + \text{near}} & 0 & 1
\end{pmatrix}
\]
The current matrix is multiplied by this matrix with the result replacing the current matrix. That is, if
$M$ is the current matrix and $O$ is the ortho matrix, then $M$ is replaced with $M \cdot O$.

Use $\text{glPushMatrix}$ and $\text{glPopMatrix}$ to save and restore the current matrix stack.

**ASSOCIATED GETS**

$\text{glGet with argument GL\_MATRIX\_MODE}$

$\text{glGet with argument GL\_MODELVIEW\_MATRIX}$

$\text{glGet with argument GL\_PROJECTION\_MATRIX}$

$\text{glGet with argument GL\_TEXTURE\_MATRIX}$

**SEE ALSO**

“$\text{glFrustum}$”, “$\text{glMatrixMode}$”, “$\text{glMultMatrix}$”, “$\text{glPushMatrix}$”, “$\text{glViewport}$”

$\text{glPassThrough}$

**NAME**

$\text{glPassThrough}$ — place a marker in the feedback buffer

**C SPECIFICATION**

```c
void glPassThrough( GLfloat token )
```

**PARAMETERS**

- **token**: Specifies a marker value to be placed in the feedback buffer following a
  \text{GL\_PASS\_THROUGH\_TOKEN}.

**DESCRIPTION**

Feedback is a GL render mode. The mode is selected by calling $\text{glRenderMode}$ with
\text{GL\_FEEDBACK}. When the GL is in feedback mode, no pixels are produced by rasterization. Instead,
information about primitives that would have been rasterized is fed back to the application using the GL. See
“$\text{glFeedbackBuffer}$” for a description of the feedback buffer and the values in it.

$\text{glPassThrough}$ inserts a user-defined marker in the feedback buffer when it is executed in feedback
mode. token is returned as if it were a primitive; it is indicated with its own unique identifying value:
\text{GL\_PASS\_THROUGH\_TOKEN}. The order of $\text{glPassThrough}$ commands with respect to the
specification of graphics primitives is maintained.

**NOTES**

$\text{glPassThrough}$ is ignored if the GL is not in feedback mode.

**ERRORS**

$\text{GL\_INVALID\_OPERATION}$ is generated if $\text{glOrtho}$ is called between a call to $\text{glBegin}$ and the
and the corresponding call to $\text{glEnd}$.

**ASSOCIATED GETS**

$\text{glGet with argument GL\_RENDER\_MODE}$

**SEE ALSO**

“$\text{glFeedbackBuffer}$”, “$\text{glRenderMode}$”
**glPixelMap**

**NAME**
glPixelMapfv, glPixelMapuiv, glPixelMapusv — set up pixel transfer maps

**C SPECIFICATION**

```c
void glPixelMapf(GLenum map, GLint mapsize, const GLfloat *values) {
    // Implementation
}

void glPixelMapuiv(GLenum map, GLint mapsize, const GLuint *values) {
    // Implementation
}

void glPixelMapusv(GLenum map, GLint mapsize, const GLushort *values) {
    // Implementation
}
```

**PARAMETERS**

- `map`: Specifies a symbolic map name. Must be one of the following:
  - GL_PIXEL_MAP_I_TO_I
  - GL_PIXEL_MAP_S_TO_S
  - GL_PIXEL_MAP_I_TO_R
  - GL_PIXEL_MAP_I_TO_G
  - GL_PIXEL_MAP_I_TO_B
  - GL_PIXEL_MAP_I_TO_A
  - GL_PIXEL_MAP_R_TO_R
  - GL_PIXEL_MAP_G_TO_G
  - GL_PIXEL_MAP_B_TO_B
  - GL_PIXEL_MAP_A_TO_A

- `mapsize`: Specifies the size of the map being defined.

- `values`: Specifies an array of `mapsize` values.

**DESCRIPTION**

`glPixelMap` sets up translation tables, or maps, used by `glDrawPixels` `glReadPixels` `glCopyPixels` `glTexImage1D`, and `glTexImage2D`. Use of these maps is described completely in the `glPixelTransfer` reference page, and partly in the reference pages for the pixel and texture image commands. Only the specification of the maps is described in this reference page.

- `map` is a symbolic map name, indicating one of ten maps to set. `mapsize` specifies the number of entries in the map, and `values` is a pointer to an array of `mapsize` values.

The ten maps are as follows:

- **GL_PIXEL_MAP_I_TO_I**
  Maps color indices to color indices.

- **GL_PIXEL_MAP_S_TO_S**
  Maps stencil indices to stencil indices.

- **GL_PIXEL_MAP_I_TO_R**
  Maps color indices to red components.

- **GL_PIXEL_MAP_I_TO_G**
  Maps color indices to green components.

- **GL_PIXEL_MAP_I_TO_B**
  Maps color indices to blue components.

- **GL_PIXEL_MAP_I_TO_A**
  Maps color indices to alpha components.

- **GL_PIXEL_MAP_R_TO_R**
  Maps red components to red components.

- **GL_PIXEL_MAP_G_TO_G**
  Maps green components to green components.

- **GL_PIXEL_MAP_B_TO_B**
  Maps blue components to blue components.

- **GL_PIXEL_MAP_A_TO_A**
  Maps alpha components to alpha components.

The entries in a map can be specified as single-precision floating-point numbers, unsigned short integers, or unsigned long integers. Maps that store color component values (all but `GL_PIXEL_MAP_I_TO_I` and `GL_PIXEL_MAP_S_TO_S`) retain their values in floating-point format, with unspecified mantissa and exponent sizes. Floating-point values specified by `glPixelMapfv` are converted directly to the internal floating-point format of these maps, then clamped to the range [0,1]. Unsigned integer values specified by `glPixelMapusv` and `glPixelMapuiv` are converted linearly such that the largest representable integer maps to 1.0, and zero maps to 0.0.

Maps that store indices, `GL_PIXEL_MAP_I_TO_I` and `GL_PIXEL_MAP_S_TO_S`, retain their values in fixed-point format, with an unspecified number of bits to the right of the binary point. Floating-point values specified by `glPixelMapfv` are converted directly to the internal fixed-point format of these maps. Unsigned integer values specified by `glPixelMapusv` and `glPixelMapuiv` specify integer values, with all zeros to the right of the binary point.

The table below shows the initial sizes and values for each of the maps. Maps that are indexed by `GL_PIXEL_MAP_I_TO_I` or `GL_PIXEL_MAP_S_TO_S` must have `mapsize` = 2^n for some `n` or results are undefined. The maximum allowable size for each map depends on the implementation and can be determined by calling `glGet` with argument `GL_MAX_PIXEL_MAP_TABLE`. The single maximum applies to all maps, and it is at least 32.

<table>
<thead>
<tr>
<th>Map Type</th>
<th>Lookup Index</th>
<th>Lookup Value</th>
<th>Initial Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL_PIXEL_MAP_I_TO_I</td>
<td>color index</td>
<td>color index</td>
<td>1</td>
</tr>
<tr>
<td>GL_PIXEL_MAP_S_TO_S</td>
<td>stencil index</td>
<td>stencil index</td>
<td>1</td>
</tr>
<tr>
<td>GL_PIXEL_MAP_I_TO_R</td>
<td>color index</td>
<td>R</td>
<td>1</td>
</tr>
<tr>
<td>GL_PIXEL_MAP_I_TO_G</td>
<td>color index</td>
<td>G</td>
<td>1</td>
</tr>
<tr>
<td>GL_PIXEL_MAP_I_TO_B</td>
<td>color index</td>
<td>B</td>
<td>1</td>
</tr>
<tr>
<td>GL_PIXEL_MAP_I_TO_A</td>
<td>color index</td>
<td>A</td>
<td>1</td>
</tr>
</tbody>
</table>

**ERRORS**

- **GL_INVALID_ENUM** is generated if `map` is not an accepted value.
- **GL_INVALID_VALUE** is generated if `mapsize` is negative or larger than `GL_MAX_PIXEL_MAP_TABLE`.
- **GL_INVALID_OPERATION** is generated if `glPixelMap` is called between a call to `glBegin` and the corresponding `glEnd`.

**ASSOCIATED GETS**

- `glGetPixelMap` `glGet` with argument `GL_PIXEL_MAP_I_TO_I_SIZE` `glGet` with argument `GL_PIXEL_MAP_S_TO_S_SIZE` `glGet` with argument `GL_PIXEL_MAP_I_TO_R_SIZE` `glGet` with argument `GL_PIXEL_MAP_I_TO_G_SIZE` `glGet` with argument `GL_PIXEL_MAP_I_TO_B_SIZE` `glGet` with argument `GL_PIXEL_MAP_I_TO_A_SIZE` `glGet` with argument `GL_PIXEL_MAP_R_TO_R_SIZE` `glGet` with argument `GL_PIXEL_MAP_G_TO_G_SIZE` `glGet` with argument `GL_PIXEL_MAP_B_TO_B_SIZE` `glGet` with argument `GL_PIXEL_MAP_A_TO_A_SIZE`
components or indices, where n is the number of components or indices in a pixel. k is the number of pixels in a row (GL_PACK_ROW_LENGTH) if it is greater than zero, the width argument to the pixel routine otherwise, a is the value of GL_PACK_ALIGNMENT, and s is the size, in bytes, of a single component (if a < s, then it is as if a = s). In the case of 1-bit values, the location of the next row is obtained by skipping

\[ k = \frac{8a}{8a} \]

components or indices. The word component in this description refers to the non-index values red, green, blue, alpha, and depth. Storage format GL_RGB, for example, has three components per pixel: first red, then green, and finally blue.

\( \text{GL_PACK_SKIP_PIXELS and GL_PACK_SKIP_ROWS} \)

These values are provided as a convenience to the programmer; they provide no functionality that cannot be duplicated simply by incrementing the pointer passed to \( \text{glReadPixels} \). Setting GL_PACK_SKIP_PIXELS to \( i \) is equivalent to incrementing the pointer by \( i \) components or indices in each pixel. Setting GL_PACK_SKIP_ROWS to \( j \) is equivalent to incrementing the pointer by \( j \) components or indices, where \( k \) is the number of components or indices per row, as computed above in the GL_PACK_ROW_LENGTH section.

**GL_PACK_ALIGNMENT**

Specifies the alignment requirements for the start of each pixel row in memory. The allowable values are 1 (byte-alignment), 2 (rows aligned to even-numbered bytes), 4 (word alignment), and 8 (rows start on double-word boundaries).

The other six of the twelve storage parameters affect how pixel data is read back to client memory. These values are significant for glReadPixels, glTexImage1D, glTexImage2D, glBitmap, and glPolygonStipple. They are as follows:

**GL_PACK_SWAP_BYTES**

If true, byte ordering for multibyte color components, depth components, color indices, or stencil indices is reversed. That is, if a four-byte component is made up of bytes \( b, b, b, b \), it is stored in memory as \( b, b, b, b \). If GL_PACK_SWAP_BYTES is true, GL_PACK_SWAP_BYTES has no effect on the memory order of components within a pixel, only on the order of bytes within components or indices. For example, the three components of a GL_RGB format pixel are always stored with red first, green second, and blue third, regardless of the value of GL_PACK_SWAP_BYTES.

**GL_PACK_LSB_FIRST**

If true, bits are ordered within a byte from least significant to most significant; otherwise, the first bit in each byte is the most significant one. This parameter is significant for bitmap data only.

**GL_PACK_ROW_LENGTH**

If greater than zero, GL_PACK_ROW_LENGTH defines the number of pixels in a row. If the first pixel of a row is placed at location \( p \) in memory, then the location of the first pixel of the next row is obtained by skipping

\[ k \times \text{GL_PACK_ROW_LENGTH} + \text{GL_PACK_LSB_FIRST} + \text{GL_PACK_SKIP_PIXELS} + \text{GL_PACK_SKIP_ROWS} \]
the first pixel of the next row is obtained by skipping

$$k = \begin{cases} \frac{nl}{a} & s < a \\ \frac{snl}{a} & s \geq a \end{cases}$$

components or indices, where $n$ is the number of components or indices in a pixel, $l$ is the number of pixels in a row (GL_UNPACK_ROW_LENGTH if it is greater than zero, the width argument to the pixel routine otherwise), and $s$ is the value of GL_UNPACK_ALIGNMENT, and $s$ is the size, in bytes, of a single component (if $a < s$, then it is as if $a = s$). In the case of 1-bit values, the location of the next row is obtained by skipping

$$k = 8a \left[ \frac{nl}{8a} \right]$$

components or indices. The word component in this description refers to the nonindex values red, green, blue, alpha, and depth. Storage format GL_RGB, for example, has three components per pixel: first red, then green, and finally blue.

GL_UNPACK_SKIP_PIXELS and GL_UNPACK_SKIP_ROWS

These values are provided as a convenience to the programmer; they provide no functionality that cannot be duplicated simply by incrementing the pointer passed to glDrawPixels, glTexImage1D, glTexImage2D, glBitmap, or glPolygonStipple. Setting GL_UNPACK_SKIP_PIXELS to $i$ is equivalent to incrementing the pointer by $i$ components or indices, where $i$ is the number of components or indices in each pixel. Setting GL_UNPACK_SKIP_ROWS to $j$ is equivalent to incrementing the pointer by $j$ components or indices, where $j$ is the number of components or indices per row, as computed above in the GL_UNPACK_ROW_LENGTH section.

GL_UNPACK_ALIGNMENT

Specifies the alignment requirements for the start of each pixel row in memory. The allowable values are 1 (byte-alignment), 2 (words aligned to even-numbered bytes), 4 (word alignment), and 8 (rows start on double-word boundaries).

The following table gives the type, initial value, and range of valid values for each of the storage parameters that can be set with glPixelStore.

<table>
<thead>
<tr>
<th>pname</th>
<th>type</th>
<th>initial value</th>
<th>valid range</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL_PACK_SWAP_BYTES</td>
<td>Boolean</td>
<td>false</td>
<td>true or false</td>
</tr>
<tr>
<td>GL_PACK_LSB_FIRST</td>
<td>Boolean</td>
<td>false</td>
<td>true or false</td>
</tr>
<tr>
<td>GL_PACK_ROW_LENGTH</td>
<td>integer</td>
<td>0</td>
<td>[0, inf)</td>
</tr>
<tr>
<td>GL_PACK_SKIP_ROWS</td>
<td>integer</td>
<td>0</td>
<td>[0, inf)</td>
</tr>
<tr>
<td>GL_PACK_SKIP_PIXELS</td>
<td>integer</td>
<td>0</td>
<td>[0, inf)</td>
</tr>
<tr>
<td>GL_PACK_ALIGNMENT</td>
<td>integer</td>
<td>4</td>
<td>1, 2, 4, or 8</td>
</tr>
<tr>
<td>GL_UNPACK_SWAP_BYTES</td>
<td>Boolean</td>
<td>false</td>
<td>true or false</td>
</tr>
<tr>
<td>GL_UNPACK_LSB_FIRST</td>
<td>Boolean</td>
<td>false</td>
<td>true or false</td>
</tr>
<tr>
<td>GL_UNPACK_ROW_LENGTH</td>
<td>integer</td>
<td>0</td>
<td>[0, inf)</td>
</tr>
<tr>
<td>GL_UNPACK_SKIP_ROWS</td>
<td>integer</td>
<td>0</td>
<td>[0, inf)</td>
</tr>
<tr>
<td>GL_UNPACK_SKIP_PIXELS</td>
<td>integer</td>
<td>0</td>
<td>[0, inf)</td>
</tr>
<tr>
<td>GL_UNPACK_ALIGNMENT</td>
<td>integer</td>
<td>4</td>
<td>1, 2, 4, or 8</td>
</tr>
</tbody>
</table>

glPixelStore can be used to set any pixel store parameter. If the parameter type is Boolean, then if $param$ is 0.0, the parameter is false; otherwise it is set to true. If $pname$ is an integer type parameter, $param$ is converted to floating point before being assigned to real-valued parameters.

Likewise, glPixelStore can also be used to set any of the pixel store parameters. Boolean parameters are set to false if $param$ is 0 and true otherwise. $param$ is converted to floating point before being assigned to real-valued parameters.

NOTES

The pixel storage modes in effect when glDrawPixels, glReadPixels, glTexImage1D, glTexImage2D, glBitmap, or glPolygonStipple is placed in a display list control the interpretation of memory data. The pixel storage modes in effect when a display list is executed are not significant.

ERRORS

GL_INVALID_ENUM is generated if $pname$ is not an accepted value.

GL_INVALID_VALUE is generated if a negative row length, pixel skip, or row skip value is specified, or if alignment is specified as other than 1, 2, 4, or 8.

GL_INVALID_OPERATION is generated if glPixelStore is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

glGet with argument GL_PACK_SWAP_BYTES

glGet with argument GL_PACK_LSB_FIRST

glGet with argument GL_PACK_ROW_LENGTH

glGet with argument GL_PACK_SKIP_ROWS

glGet with argument GL_PACK_SKIP_PIXELS

glGet with argument GL_UNPACK_SWAP_BYTES

glGet with argument GL_UNPACK_LSB_FIRST

glGet with argument GL_UNPACK_ROW_LENGTH

glGet with argument GL_UNPACK_SKIP_ROWS

glGet with argument GL_UNPACK_SKIP_PIXELS

glGet with argument GL_UNPACK_ALIGNMENT

SEE ALSO

"glBitmap", "glDrawPixels", "glPixelMap", "glPixelTransfer", "glPixelZoom", "glPolygonStipple", "glReadPixels", "glTexImage1D", "glTexImage2D"
**glPixelTransfer**

**NAME**

`glPixelTransfer`, `glPixelTransfer` — set pixel transfer modes

**C SPECIFICATION**

```c
void glPixelTransferf( GLenum pname, GLfloat param )
void glPixelTransferi( GLenum pname, GLint param )
```

**PARAMETERS**

- `pname` Specifies the symbolic name of the pixel transfer parameter to be set. Must be one of the following:
  - `GL_MAP_COLOR`
  - `GL_MAP_STENCIL`
  - `GL_INDEX_SHIFT`
  - `GL_INDEX_OFFSET`
  - `GL_RED_SCALE`
  - `GL_RED_BIAS`
  - `GL_GREEN_SCALE`
  - `GL_GREEN_BIAS`
  - `GL_BLUE_SCALE`
  - `GL_BLUE_BIAS`
  - `GL_ALPHA_SCALE`
  - `GL_ALPHA_BIAS`
  - `GL_DEPTH_SCALE`
  - `GL_DEPTH_BIAS`

- `param` Specifies the value that `pname` is set to.

**DESCRIPTION**

`glPixelTransfer` sets pixel transfer modes that affect the operation of subsequent `glDrawPixels`, `glReadPixels`, `glCopyPixels`, `glTexImage1D`, and `glTexImage2D` commands. The algorithms that are specified by pixel transfer modes operate on pixels after they are read from the frame buffer (`glReadPixels` and `glCopyPixels`) or unpacked from client memory (`glDrawPixels`, `glTexImage1D`, and `glTexImage2D`). Pixel transfer operations happen in the same order, and in the same manner, regardless of the command that resulted in the pixel operation. Pixel storage modes (see `glPixelStore`) control the unpacking of pixels being read from client memory, and the packing of pixels being written back into client memory.

Pixel transfer operations handle four fundamental pixel types: color, color index, depth, and stencil. Color pixels are made up of four floating-point values with unspecified mantissa and exponent sizes, scaled such that 0.0 represents zero intensity and 1.0 represents full intensity. Color indices comprise a single fixed−point value, with unspecified precision to the right of the binary point. Depth pixels comprise a single floating−point value, with unspecified mantissa and exponent sizes, scaled such that 0.0 represents the minimum depth buffer value, and 1.0 represents the maximum depth buffer value. Finally, stencil pixels comprise a single fixed−point value, with unspecified precision to the right of the binary point. The pixel transfer operations performed on the four basic pixel types are as follows:

**Color**

- Each of the four color components is multiplied by a scale factor, then added to a bias factor. That is, the red component is multiplied by `GL_RED_SCALE`, then added to `GL_RED_BIAS`, the green component is multiplied by `GL_GREEN_SCALE`, then added to `GL_GREEN_BIAS`, the blue component is multiplied by `GL_BLUE_SCALE`, then added to `GL_BLUE_BIAS`, and the alpha component is multiplied by `GL_ALPHA_SCALE`, then added to `GL_ALPHA_BIAS`. After all four color components are scaled and biased, each is clamped to the range [0,1]. All color scale and bias values are specified with `glPixelTransferf`.

If `GL_MAP_COLOR` is true, each color component is scaled by the size of the corresponding color−to−color map, then replaced by the contents of that map indexed by the scaled component. That is, the red component is scaled by `GL_PIXEL_MAP_R_TO_R_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_R_TO_R` indexed by itself. The green component is scaled by `GL_PIXEL_MAP_G_TO_G_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_G_TO_G` indexed by itself. The blue component is scaled by `GL_PIXEL_MAP_B_TO_B_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_B_TO_B` indexed by itself. And the alpha component is scaled by `GL_PIXEL_MAP_A_TO_A_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_A_TO_A` indexed by itself. All components taken from the maps are then clamped to the range [0,1]. `GL_MAP_COLOR` is specified with `glPixelTransfer`. The contents of the various maps are specified with `glPixelMap`. Each color index is shifted left by `GL_INDEXSHIFT` bits, filling with zeros any bits beyond the number of fraction bits carried by the fixed−point index. If `GL_INDEX_SHIFT` is negative, the shift is to the right, again zero filled. Then `GL_INDEX_OFFSET` is added to the index. `GL_INDEX_SHIFT` and `GL_INDEX_OFFSET` are specified with `glPixelTransferi`.

**Depth**

- Each depth value is multiplied by `GL_DEPTH_SCALE`, then replaced by the contents of `GL_DEPTH_BIAS`. Depth pixels are made up of four floating-point values with unspecified mantissa and exponent sizes, scaled such that 0.0 represents the minimum depth buffer value, and 1.0 represents the maximum depth buffer value. All components from the maps are then clamped to the range [0,1]. The contents of the four maps are specified with `glPixelMap`. If the resulting pixels are to be written to an RGBA color buffer, or if they are being read back to client memory in a format other than `GL_COLOR_INDEX`, the pixel is converted from indices to colors by referencing the four maps `GL_PIXEL_MAP_I_TO_R_SIZE`, `GL_PIXEL_MAP_I_TO_G`, `GL_PIXEL_MAP_I_TO_B`, and `GL_PIXEL_MAP_I_TO_A`. Before being dereferenced, the index is masked by `2^n − 1`, where `n` is `GL_PIXEL_MAP_I_TO_I_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_I_TO_I` indexed by the masked value. `GL_MAP_COLOR` is specified with `glPixelTransfer`. The contents of the index map are specified with `glPixelMap`.

**Stencil**

- Each index is shifted `GL_INDEX_SHIFT` bits just as a color index is, then added to `GL_INDEX_OFFSET`. If `GL_MAP_STENCIL` is true, each index is masked by `2^n − 1`, where `n` is `GL_PIXEL_MAP_S_TO_S_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_S_TO_S` indexed by the masked value. All components from the maps are then clamped to the range [0,1]. The contents of the four maps are specified with `glPixelMap`. If the resulting pixels are to be written to a stencil buffer, or if they are being read back to client memory in a format other than `GL_STENCIL_INDEX`, the index is converted from indices to colors by referencing the four maps `GL_PIXEL_MAP_S_TO_R_SIZE`, `GL_PIXEL_MAP_S_TO_G`, `GL_PIXEL_MAP_S_TO_B`, and `GL_PIXEL_MAP_S_TO_A`. Before being dereferenced, the index is masked by `2^n − 1`, where `n` is `GL_PIXEL_MAP_S_TO_S_SIZE`, then replaced by the contents of `GL_PIXEL_MAP_S_TO_S` indexed by the masked value. `GL_MAP_STENCIL` is specified with `glPixelTransfer`. The contents of the index map are specified with `glPixelMap`.

The following table gives the type, initial value, and range of valid values for each of the pixel transfer parameters that are set with `glPixelTransfer`.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Type</th>
<th>Initial Value</th>
<th>Valid Range</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>GL_MAP_COLOR</code></td>
<td>Boolean</td>
<td>false</td>
<td>true/false</td>
</tr>
<tr>
<td><code>GL_MAP_STENCIL</code></td>
<td>Boolean</td>
<td>false</td>
<td>true/false</td>
</tr>
<tr>
<td><code>GL_INDEX_SHIFT</code></td>
<td>integer</td>
<td>0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_INDEX_OFFSET</code></td>
<td>integer</td>
<td>0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_RED_SCALE</code></td>
<td>float</td>
<td>1.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_RED_BIAS</code></td>
<td>float</td>
<td>0.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_GREEN_SCALE</code></td>
<td>float</td>
<td>1.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_GREEN_BIAS</code></td>
<td>float</td>
<td>0.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_BLUE_SCALE</code></td>
<td>float</td>
<td>1.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_BLUE_BIAS</code></td>
<td>float</td>
<td>0.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_ALPHA_SCALE</code></td>
<td>float</td>
<td>1.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_ALPHA_BIAS</code></td>
<td>float</td>
<td>0.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_DEPTH_SCALE</code></td>
<td>float</td>
<td>0.0</td>
<td>(-inf, inf)</td>
</tr>
<tr>
<td><code>GL_DEPTH_BIAS</code></td>
<td>float</td>
<td>0.0</td>
<td>(-inf, inf)</td>
</tr>
</tbody>
</table>
glPixelZoom

NAME

glPixelZoom — specify the pixel zoom factors

C SPECIFICATION

void glPixelZoom( GLfloat xfactor, GLfloat yfactor )

PARAMETERS

xfactor, yfactor Specify the x and y zoom factors for pixel write operations.

DESCRIPTION

glPixelZoom specifies values for the x and y zoom factors. During the execution of glDrawPixels or glCopyPixels if $(x_r, y_r)$ is the current raster position, and a given element is in the nth row and mth column of the pixel rectangle, then pixels whose centers are in the rectangle with corners at

$$(x_r + n \cdot xfactor, y_r + m \cdot yfactor)$$

are candidates for replacement. Any pixel whose center lies on the bottom or left edge of this rectangular region is also modified.

Pixel zoom factors are not limited to positive values. Negative zoom factors reflect the resulting image about the current raster position.

NOTES

If a glDrawPixels, glReadPixels, glCopyPixels, glTexImage1D, or glTexImage2D command is placed in a display list (see "glNewList" and "glCallList"), the pixel transfer mode settings in effect when the display list is executed are the ones that are used. They may be different from the settings when the command was compiled into the display list.

GL_INVALID_ENUM is generated if pname is not an accepted value.

GL_INVALID_OPERATION is generated if glPixelTransfer is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

gGet with argument GL_ZOOM_X

gGet with argument GL_ZOOM_Y

SEE ALSO

"glCopyPixels", "glDrawPixels"

NAME

glPointSize — specify the diameter of rasterized points

C SPECIFICATION

void glPointSize( GLfloat size )

PARAMETERS

size Specifies the diameter of rasterized points. The default is 1.0.

DESCRIPTION

glPointSize specifies the rasterized diameter of both aliased and antialiased points. Using a point size other than 1.0 has different effects, depending on whether point antialiasing is enabled. Point antialiasing is controlled by calling glEnable and glDisable with argument GL_POINT_SMOOTH.

If point antialiasing is disabled, the actual size is determined by rounding the supplied size to the nearest integer. (If the rounding results in the value 0, it is as if the point size were 1.) If the rounded...
size is odd, then the center point \((x, y)\) of the pixel fragment that represents the point is computed as

\[
\left(\lceil x_w \rceil + .5, \lceil y_w \rceil + .5\right)
\]

where \(w\) subscripts indicate window coordinates. All pixels that lie within the square grid of the rounded size centered at \((x, y)\) make up the fragment. If the size is even, the center point is

\[
\left(\lfloor x_w + .5 \rfloor, \lfloor y_w + .5 \rfloor\right)
\]

and the rasterized fragment’s centers are the half-integer window coordinates within the square of the rounded size centered at \((x, y)\). All pixel fragments produced in rasterizing a nonantialiased point are assigned the same associated data, that of the vertex corresponding to the point.

If antialiasing is enabled, then point rasterization produces a fragment for each pixel square that intersects the region lying within the circle having diameter equal to the current point size and centered at the point’s \((x_w, y_w)\). The coverage value for each fragment is the window coordinate area of the intersection of the circular region with the corresponding pixel square. This value is saved and used in the final rasterization step. The data associated with each fragment is the data associated with the point being rasterized.

NOTES
The point size specified by \texttt{glPointSize} is always returned when \texttt{GL_POINT_SIZE} is queried. Clamping and rounding for aliased and antialiased points have no effect on the specified value. Non-antialiased point size may be clamped to an implementation-dependent maximum. Although this maximum cannot be queried, it must be no less than the maximum value for antialiased points, rounded to the nearest integer value.

ERRORS
\texttt{GL_INVALID_VALUE} is generated if size is less than or equal to zero.
\texttt{GL_INVALID_OPERATION} is generated if \texttt{glPointSize} is called between a call to \texttt{glBegin} and the corresponding call to \texttt{glEnd}.

ASSOCIATED GETS
\texttt{glGet} with argument \texttt{GL_POINT_SIZE}
\texttt{glGet} with argument \texttt{GL_POINT_SIZE_RANGE}
\texttt{glGet} with argument \texttt{GL_POINT_SIZE_GRANULARITY}

SEE ALSO
"glEnable", \texttt{glPointSmooth}
\texttt{glPolygonMode}

NAME
\texttt{glPolygonMode} — select a polygon rasterization mode

C SPECIFICATION
void \texttt{glPolygonMode}(GLenum face, GLenum mode)

PARAMETERS

- \texttt{face} Specifies the polygons that \texttt{mode} applies to. Must be \texttt{GL_FRONT} for front-facing polygons, \texttt{GL_BACK} for back-facing polygons, or \texttt{GL_FRONT_AND_BACK} for both front- and back-facing polygons.
- \texttt{mode} Specifies the way polygons will be rasterized. Accepted values are \texttt{GL_POINT}, \texttt{GL_LINE}, and \texttt{GL_FILL}. The default is \texttt{GL_FILL} for both front- and back-facing polygons.

DESCRIPTION
\texttt{glPolygonMode} controls the interpretation of polygons for rasterization, \texttt{face} describes which polygons \texttt{mode} applies to: front-facing polygons (\texttt{GL_FRONT}), back-facing polygons (\texttt{GL_BACK}), or both (\texttt{GL_FRONT_AND_BACK}). The polygon mode affects only the final rasterization of polygons. In particular, a polygon’s vertices are lit and the polygon is clipped and possibly culled before these modes are applied.

Three modes are defined and can be specified in \texttt{mode}:
- \texttt{GL_POINT} Polygon vertices that are marked as the start of a boundary edge are drawn as points. Point attributes such as \texttt{GL_POINT_SIZE} and \texttt{GL_POINT_SMOOTH} control the rasterization of the points. Polygon rasterization attributes other than \texttt{GL_POLYGON_MODE} have no effect.
- \texttt{GL_LINE} Boundary edges of the polygon are drawn as line segments. They are treated as connected line segments for line stippling; the line stipple counter and pattern are not reset between segments (see \texttt{glLineStipple}). Line attributes such as \texttt{GL_LINE_WIDTH} and \texttt{GL_LINE_SMOOTH} control the rasterization of the lines. Polygon rasterization attributes other than \texttt{GL_POLYGON_MODE} have no effect.
- \texttt{GL_FILL} The interior of the polygon is filled. Polygon attributes such as \texttt{GL_POLYGON_STIPPLE} and \texttt{GL_POLYGON_SMOOTH} control the rasterization of the polygon.

EXAMPLES
To draw a surface with filled back-facing polygons and outlined front-facing polygons, call \texttt{glPolygonMode(GL_FRONT, GL_LINE)};

NOTES
Vertices are marked as boundary or nonboundary with an edge flag. Edge flags are generated internally by the GL when it decomposes polygons, and they can be set explicitly using `glEdgeFlag`.

**ERRORS**

- `GL_INVALID_ENUM` is generated if either `face` or `mode` is not an accepted value.
- `GL_INVALID_OPERATION` is generated if `glPolygonMode` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGet` with argument `GL_POLYGON_MODE`

**SEE ALSO**

- `"glBegin"`, `"glEdgeFlag"`, `"glLineStipple"`, `"glLineWidth"`, `"glPointSize"`, `"glPolygonStipple"`

**glPolygonStipple**

**NAME**

- `glPolygonStipple` — set the polygon stippling pattern

**C SPECIFICATION**

```c
void glPolygonStipple(const GLubyte *mask)
```

**PARAMETERS**

- `mask`: Specifies a pointer to a 32×32 stipple pattern that will be unpacked from memory in the same way that `glDrawPixels` unpacks pixels.

**DESCRIPTION**

Polygon stippling, like line stippling (see `"glLineStipple"`), masks out certain fragments produced by rasterization, creating a pattern. Stippling is independent of polygon antialiasing. A mask and its corresponding pattern is stored in memory just like the pixel data supplied to a `glDrawPixels` with height and width both equal to 32, a pixel format of `GL_COLOR_INDEX` and data type of `GL_BITMAP`. When polygon stippling is enabled, it is as if the stipple image were all ones, otherwise it is as if the stipple pattern were all zeros.

**ERRORS**

- `GL_INVALID_OPERATION` is generated if `glPolygonStipple` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**glPushAttrib**

**NAME**

- `glPushAttrib`, `glPopAttrib` — push and pop the attribute stack

**C SPECIFICATION**

```c
void glPushAttrib(GLbitfield mask)
```

**PARAMETERS**

- `mask`: Specifies a mask that indicates which attributes to save. Values for `mask` are listed in the table below.

**DESCRIPTION**

`glPushAttrib` takes one argument, a mask that indicates which groups of state variables to save on the stack. Symbolic constants are used to set bits in the mask. The special mask `GL_ALL_ATTRIB_BITS` can be used to save all stackable states.

**ASSOCIATED GETS**

- `glGetPolygonStipple`
- `glIsEnabled` with argument `GL_POLYGON_STIPPLE`
- `glPushAttrib` takes one argument, a mask that indicates which groups of state variables to save on the stack. Symbolic constants are used to set bits in the mask. The special mask `GL_ALL_ATTRIB_BITS` can be used to save all stackable states.

**C SPECIFICATION**

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**ASSOCIATED GETS**

- `glGetPolygonStipple`
- `glIsEnabled` with argument `GL_POLYGON_STIPPLE`

**SEE ALSO**

- "glDrawPixels", "glLineStipple", "gLineStipple", "glPixelStore", "glPixelTransfer"

**glPushAttrib**

**NAME**

- `glPushAttrib`, `glPopAttrib` — push and pop the attribute stack

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**ASSOCIATED GETS**

- `glGetPolygonStipple`
- `glIsEnabled` with argument `GL_POLYGON_STIPPLE`

**SEE ALSO**

- "glDrawPixels", "glLineStipple", "gLineStipple", "glPixelStore", "glPixelTransfer"

**glPushAttrib**

**NAME**

- `glPushAttrib`, `glPopAttrib` — push and pop the attribute stack

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**ASSOCIATED GETS**

- `glGetPolygonStipple`
- `glIsEnabled` with argument `GL_POLYGON_STIPPLE`

**SEE ALSO**

- "glDrawPixels", "glLineStipple", "gLineStipple", "glPixelStore", "glPixelTransfer"
GL_CURRENT_RASTER_POSITION_VALID flag
RGBA color associated with current raster position
Color index associated with current raster position
Texture coordinates associated with current raster position
GL_EDGE_FLAG flag

GL_DEPTH_BUFFER_BIT
GL_DEPTH_TEST enable bit
Depth buffer test function
Depth buffer clear value
GL_DEPTH_WRITEMASK enable bit

GL_ENABLE_BIT
GL_ALPHA_TEST flag
GL_AUTO_NORMAL flag
GL_BLEND flag
Enable bits for the user-definable clipping planes
GL_COLOR_MATERIAL
GL_CULL_FACE flag
GL_DEPTH_TEST flag
GL_DITHER flag
GL_FOG flag

GL_LIGHT: where 0 <= i < GL_MAX_LIGHTS
GL_LIGHTING flag
GL_LINE_SMOOTH flag
GL_LINE_STIPPLE flag

GL_LOGIC_OP flag
GL_MAP1_x where x is a map type
GL_MAP2_x where x is a map type
GL_NORMALIZE flag
GL_POINT_SMOOTH flag
GL_POLYGON_SMOOTH flag
GL_POLYGON_STIPPLE flag
GL_POLYGON_STIPPLE BIT

GL_STENCIL_TEST flag
GL_TEXTURE_1D flag
GL_TEXTURE_2D flag
GL_TEXTURE_3D flag
GL_TEXTURE_GEN_x where x is S, T, R, or Q

GL_EVAL_BIT
GL_MAP1_x enable bits, where x is a map type
GL_MAP2_x enable bits, where x is a map type
1-D grid endpoints and divisions
2-D grid endpoints and divisions
GL_AUTO_NORMAL enable bit

GL_FOG_BIT
GL_FOG enable flag
Fog color
Fog density
Linear fog start
Linear fog end
Fog index
GL_FOG_MODE value

GL_HINT_BIT
GL_PERSPECTIVE_CORRECTION_HINT setting
GL_POINT_SMOOTH_HINT setting
GL_LINE_SMOOTH_HINT setting
GL_POLYGON_SMOOTH_HINT setting

GL_LIGHTING_BIT
GL_COLOR_MATERIAL enable bit
GL_COLOR_MATERIAL_FACE value
Color material parameters that are tracking the current color
Ambient scene color
GL_LIGHT_MODEL_LOCAL_VIEWER value
GL_LIGHT_MODEL_TWO_SIDE setting
GL_LIGHTING enable bit
Enable bit for each light
Ambient, diffuse, and specular intensity for each light
Direction, position, exponent, and cutoff angle for each light
Constant, linear, and quadratic attenuation factors for each light
Ambient, diffuse, specular, and emissive color for each material
Specular exponent for each material

GL_LINE_BIT
GL_LINE_SMOOTH flag
GL_LINE_STIPPLE enable bit
Line stipple pattern and repeat counter
Line width
GL_LINE_BIT
GL_LIST_BASE setting

GL_PIXEL_MODE_BIT
GL_RED_BIAS and GL_RED_SCALE settings
GL_GREEN_BIAS and GL_GREEN_SCALE values
GL_BLUE_BIAS and GL_BLUE_SCALE
GL_ALPHA_BIAS and GL_ALPHA_SCALE
GL_DEPTH_BIAS and GL_DEPTH_SCALE
GL_INDEX_OFFSET and GL_INDEX_SHIFT values
GL_MAP_COLOR and GL_MAP_STENCIL flags
GL_ZOOM_X and GL_ZOOM_Y factors
GL_RELATIVE_OFFSET setting
GL_x where x is a pixal map table name
GL_x_SIZE where x is a pixal map table name

GL_POINT_BIT
GL_POINT_SMOOTH flag
Point size

GL_POLYGON_BIT
GL_CULL_FACE enable bit
GL_CULL_FACE_MODE value
GL_FRONT_FACE indicator
GL_POLYGON_MODE setting
GL_POLYGON_SMOOTH flag
GL_POLYGON_STIPPLE enable bit

GL_POLYGON_STIPPLE_BIT
Polygon stipple image

GL_SCISSOR_BIT
GL_SCISSOR_TEST flag
Scissor box

GL_STENCIL_BUFFER_BIT
GL_STENCIL_TEST enable bit
Stencil function and reference value
Stencil value mask
Stencil fail, pass, and depth buffer pass actions
Stencil buffer writemask

GL_TEXTURE_BIT
- Enable bits for the four texture coordinates
- Border color for each texture image
- Minification function for each texture image
- Magnification function for each texture image
- Texture coordinates and wrap mode for each texture image
- Color and mode for each texture environment
- Enable bits GL_TEXTURE_GEN_x for S, T, R, and Q
- GL_TEXTURE_GEN_MODE setting for S, T, R, and Q
- glTexGen plane equations for S, T, R, and Q

GL_TRANSFORM_BIT
- Coefficients of the six clipping planes
- Enable bits for the user-definable clipping planes
- GL_MATRIX_MODE value
- GL_NORMALIZE flag

GL_VIEWPORT_BIT
- Depth range (near and far)
- Viewport origin and extent

glPopAttrib restores the values of the state variables saved with the last glPushAttrib command. Those not saved are left unchanged.

It is an error to push attributes onto a full stack, or to pop attributes off an empty stack. In either case, the error flag is set and no other change is made to GL state.

Initially, the attribute stack is empty.

NOTES
Not all values for GL state can be saved on the attribute stack. For example, pixel pack and unpack state, render mode state, and select and feedback state cannot be saved.

The depth of the attribute stack depends on the implementation, but it must be at least 16.

ERRORS
GL_STACK_OVERFLOW is generated if glPushAttrib is called while the current matrix stack is full.
GL_STACK_UNDERFLOW is generated if glPopAttrib is called while the current matrix stack is empty.
GL_INVALID_OPERATION is generated if glPushAttrib is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
- glGet with argument GL_ATTRIB_STACK_DEPTH
- glGet with argument GL_MAX_ATTRIB_STACK_DEPTH

SEE ALSO
- glGetClipPlane, glGetError, glGetLight, glGetMap, glGetMaterial, glGetPixelMap, glGetPolygonStipple, glGetString, glGetTexImage, glGetTexParameter, glBindTexture, glEnable

NAME
glPushMatrix, glPopMatrix – push and pop the current matrix stack

C SPECIFICATION
void glPushMatrix( void )

C SPECIFICATION
void glPopMatrix( void )

DESCRIPTION
There is a stack of matrices for each of the matrix modes. In GL_MODELVIEW mode, the stack depth is at least 32. In the other two modes, GL_PROJECTION and GL_TEXTURE, the depth is at least 2.

The current matrix in any mode is the matrix on the top of the stack for that mode.

glPushMatrix pushes the current matrix stack down by one, duplicating the current matrix. That is, after a glPushMatrix call, the matrix on the top of the stack is identical to the one below it.

glPopMatrix pops the current matrix stack, replacing the current matrix with the one below it on the stack.

Initially, each of the stacks contains one matrix, an identity matrix.

It is an error to push a full matrix stack, or to pop a matrix stack that contains only a single matrix. In either case, the error flag is set and no other change is made to GL state.

ERRORS
GL_STACK_OVERFLOW is generated if glPushMatrix is called while the current matrix stack is full.
GL_STACK_UNDERFLOW is generated if glPopMatrix is called while the current matrix stack contains only a single matrix.
GL_INVALID_OPERATION is generated if glPushMatrix is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
- glGet with argument GL_MATRIX_MODE
- glGet with argument GL_MODELVIEW_MATRIX
- glGet with argument GL_PROJECTION_MATRIX
- glGet with argument GL_TEXTURE_MATRIX
- glGet with argument GL_MODELVIEW_STACK_DEPTH
- glGet with argument GL_PROJECTION_STACK_DEPTH
- glGet with argument GL_TEXTURE_STACK_DEPTH
- glGet with argument GL_MODELVIEW_STACK_DEPTH
- glGet with argument GL_PROJECTION_STACK_DEPTH
- glGet with argument GL_TEXTURE_STACK_DEPTH

SEE ALSO
- glFrustum, glLoadIdentity, glLoadMatrix, glMatrixMode, glMultMatrix, glOrtho, glRotate, glScale, glVertex
**glPushName**

**NAME**

`glPushName`, `glPopName` — push and pop the name stack

**C SPECIFICATION**

```c
void glPushName(GLuint name);
void glPopName(void);
```

**PARAMETERS**

- name Specifies a name that will be pushed onto the name stack.
- void

**DESCRIPTION**

The name stack is used during selection mode to allow sets of rendering commands to be uniquely identified. It consists of an ordered set of unsigned integers. `glPushName` causes name to be pushed onto the name stack, which is initially empty. `glPopName` pops one name off the top of the stack.

It is an error to push a name onto a full stack, or to pop a name off an empty stack. It is also an error to manipulate the name stack between a call to `glBegin` and the corresponding call to `glEnd`. In any of these cases, the error flag is set and no other change is made to GL state.

The name stack is always empty while the render mode is not `GL_SELECT`. Calls to `glPushName` or `glPopName` while the render mode is not `GL_SELECT` are ignored.

**ERRORS**

- `GL_STACK_OVERFLOW` is generated if `glPushName` is called while the name stack is full.
- `GL_STACK_UNDERFLOW` is generated if `glPopName` is called while the name stack is empty.
- `GL_INVALID_OPERATION` is generated if `glPushName` or `glPopName` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGet` with argument `GL_NAME_STACK_DEPTH`
- `glGet` with argument `GL_MAX_NAME_STACK_DEPTH`

**SEE ALSO**

- `glInitNames`, `glLoadName`, `glRenderMode`, `glSelectBuffer`

**glRasterPos**

**NAME**

`glRasterPos2d`, `glRasterPos2f`, `glRasterPos2i`, `glRasterPos2s`, `glRasterPos3d`, `glRasterPos3f`, `glRasterPos3i`, `glRasterPos3s`, `glRasterPos4d`, `glRasterPos4f`, `glRasterPos4i`, `glRasterPos4s`, `glRasterPos4dv`, `glRasterPos4fv`, `glRasterPos4iv`, `glRasterPos4sv` — specify the raster position for pixel operations

**C SPECIFICATION**

```c
void glRasterPos2d(GLdouble x, GLdouble y);
void glRasterPos2f(GLfloat x, GLfloat y);
void glRasterPos2i(GLint x, GLint y);
void glRasterPos2s(GLshort x, GLshort y);
void glRasterPos3d(GLdouble x, GLdouble y, GLdouble z);
void glRasterPos3f(GLfloat x, GLfloat y, GLfloat z);
void glRasterPos3i(GLint x, GLint y, GLint z);
void glRasterPos3s(GLshort x, GLshort y, GLshort z);
void glRasterPos4d(GLdouble x, GLdouble y, GLdouble z, GLdouble w);
void glRasterPos4f(GLfloat x, GLfloat y, GLfloat z, GLfloat w);
void glRasterPos4i(GLint x, GLint y, GLint z, GLint w);
void glRasterPos4s(GLshort x, GLshort y, GLshort z, GLshort w);
```

**PARAMETERS**

- `x, y, z, w` Specify the x, y, z, and w object coordinates (if present) for the raster position.

**DESCRIPTION**

The GL maintains a 3-D position in window coordinates. This position, called the raster position, is maintained with subpixel accuracy. It is used to position pixel and bitmap write operations. See "glBitmap", "glDrawPixels", and "glCopyPixels".

The current raster position consists of three window coordinates (x, y, z), a clip coordinate w value, an eye coordinate distance, a valid bit, and associated color data and texture coordinates. The eye coordinate is a clip coordinate; because w is not projected to window coordinates. `glRasterPos4f` specifies object coordinates x, y, z, and w explicitly. `glRasterPos3f` specifies object coordinates x, y, and z, and w implicitly, while w is implicitly set to one. `glRasterPos2f` uses the argument values for x and y while implicitly setting z and w to zero and one.

The object coordinates presented by `glRasterPos` are treated just like those of a `glVertex` command: They are transformed by the current modelview and projection matrices and passed to the clipping stage. If the vertex is not culled, then it is projected and scaled to window coordinates, which become the new current raster position, and the `GL_CURRENT_RASTER_POSITION_VALID` flag is set. If
the vertex is culled, then the valid bit is cleared and the current raster position and associated color and texture coordinates are undefined.

The current raster position also includes some associated color data and texture coordinates. If lighting is enabled, then GL_CURRENT_RASTER_COLOR, in RGBA mode, or the GL_CURRENT_RASTER_INDEX, in color index mode, is set to the color produced by the lighting calculation (see "glLight", "glLightModel", and "glShadeModel"). If lighting is disabled, current color (in RGBA mode, state variable GL_CURRENT_COLOR) or color index (in color index mode, state variable GL_CURRENT_INDEX) is used to update the current raster color.

Likewise, GL_CURRENT_RASTER_TEXTURE_COORDS is updated as a function of GL_CURRENT_TEXTURE_COORDS, based on the texture matrix and the texture generation functions (see "glTexGen"). Finally, the distance from the origin of the eye coordinate system to the vertex as transformed by only the modelview matrix replaces GL_CURRENT_RASTER_DISTANCE.

Initially, the current raster position is (0,0,0,1), the current raster distance is 0, the valid bit is set, the associated RGBA color is (1,1,1,1), the associated color index is 1, and the associated texture coordinates are (0, 0, 0, 1). In RGBA mode, GL_CURRENT_RASTER_INDEX is always 1; in color index mode, the current raster RGBA color always maintains its initial value.

NOTES
The raster position is modified both by glRasterPos and by glBitmap.
When the raster position coordinates are invalid, drawing commands that are based on the raster position are ignored (that is, they do not result in changes to GL state).

ERRORS
GL_INVALID_OPERATION is generated if glRasterPos is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_CURRENT_RASTER_POSITION
glGet with argument GL_CURRENT_RASTER_POSITION_VALID
glGet with argument GL_CURRENT_RASTER_DISTANCE
glGet with argument GL_CURRENT_RASTER_COLOR
glGet with argument GL_CURRENT_RASTER_INDEX
glGet with argument GL_CURRENT_RASTER_TEXTURE_COORDS

SEE ALSO
"glBitmap", "glCopyPixels", "glDrawBuffer", "glReadPixels", "glTexCoord", "glTexGen", "glVertex"

glReadBuffer

NAME
glReadBuffer — select a color buffer source for pixels

C SPECIFICATION
void glReadBuffer (GLenum mode)

PARAMETERS
mode Specifies a color buffer. Accepted values are GL_FRONT_LEFT, GL_FRONT_RIGHT, GL_BACK_LEFT, GL_BACK_RIGHT, GL_FRONT, GL_BACK, and GL_AUX, where i is between 0 and GL_AUX_BUFFERS – 1.

DESCRIPTION
glReadBuffer specifies a color buffer as the source for subsequent glReadPixels and glCopyPixels commands. mode accepts one of twelve or more predefined values. (GL_AUX0 through GL_AUX3 are always defined.) In a fully configured system, GL_FRONT, GL_BACK, GL_FRONT_LEFT, and GL_FRONT_RIGHT all name the front left buffer, GL_FRONT_RIGHT and GL_RIGHT name the front right buffer, and GL_BACK_LEFT and GL_BACK name the back left buffer. Nonstereo configurations have only a left buffer, or a front left and a back left buffer if double-buffered. Single-buffered configurations have only a front buffer, or a front left and a front right buffer if stereo. It is an error to specify a nonexistent buffer to glReadBuffer.

By default, mode is GL_FRONT in single-buffered configurations, and GL_BACK in double-buffered configurations.

ERRORS
GL_INVALID_ENUM is generated if mode is not one of the twelve (or more) accepted values.
GL_INVALID_OPERATION is generated if glReadBuffer is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_READ_BUFFER

SEE ALSO
"glCopyPixels", "glDrawBuffer", "glReadPixels"

glReadPixels

NAME
glReadPixels — read a block of pixels from the frame buffer

C SPECIFICATION
void glReadPixels (GLint x, GLint y, GLsizei width, GLsizei height, GLenum format, GLenum type, GLvoid *pixels)

PARAMETERS
x, y Specify the window coordinates of the first pixel that is read from the frame buffer. This location is the lower left corner of a rectangular block of pixels.
width, height Specify the dimensions of the pixel rectangle. width and height of one correspond to a single pixel.
format Specifies the format of the pixel data. The following symbolic values are accepted: GL_COLOR_INDEX, GL_STENCIL_INDEX, GL_DEPTH_COMPONENT.
then multiplied by GL\_c\_SCALE and added to GL\_c\_BIAS, where c is GL\_RED, GL\_GREEN, GL\_BLUE, and GL\_ALPHA. Each component is clamped to the range [0,1]. Finally, if GL\_MAP\_COLOR is GL\_TRUE, each color component c is replaced by its mapping in the table GL\_PIXEL\_MAP\_c\_TO\_c, where c again is GL\_RED, GL\_GREEN, GL\_BLUE, and GL\_ALPHA. Each component is scaled to the size its corresponding table before the lookup is performed.

Finally, unneeded data is discarded. For example, GL\_RED discards the green, blue, and alpha components, while GL\_RGB discards only the alpha component.

GL\_LUMINANCE computes a single component value as the sum of the red, green, and blue components, and GL\_LUMINANCE\_ALPHA does the same, while keeping alpha as a second value.

The shift, scale, bias, and lookup factors described above are all specified by gl\_Pixel\_Transfer. The lookup table contents themselves are specified by gl\_Pixel\_Map.

The final step involves converting the indices or components to the proper format, as specified by type. If format is GL\_COLOR\_INDEX or GL\_STENCIL\_INDEX and type is not GL\_FLOAT, each index is masked with the mask value given in the following table. If type is GL\_FLOAT, then each integer index is converted to single-precision floating-point format.

If format is GL\_RED, GL\_GREEN, GL\_BLUE, GL\_ALPHA, GL\_RGB, GL\_RGBA, GL\_LUMINANCE, or GL\_LUMINANCE\_ALPHA and type is not GL\_FLOAT, each component is multiplied by the multiplier shown in the following table. If type is GL\_FLOAT, then each component is passed as is (or converted to the client's single-precision floating-point format if it is different from the one used by the GL).

<table>
<thead>
<tr>
<th>type</th>
<th>index mask</th>
<th>component conversion</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL_UNSIGNED_BYTE</td>
<td>((2^8 - 1))</td>
<td>((2^8 - 1)) * c</td>
</tr>
<tr>
<td>GL_BYTE</td>
<td>((2^7 - 1))</td>
<td>((2^7 - 1)) * c - 1/2</td>
</tr>
<tr>
<td>GL_BITMAP</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>GL_UNSIGNED_SHORT</td>
<td>((2^16 - 1))</td>
<td>((2^16 - 1)) * c - 1/2</td>
</tr>
<tr>
<td>GL_SHORT</td>
<td>((2^15 - 1))</td>
<td>((2^15 - 1)) * c - 1/2</td>
</tr>
<tr>
<td>GL_UNSIGNED_INT</td>
<td>((2^32 - 1))</td>
<td>((2^32 - 1)) * c - 1/2</td>
</tr>
<tr>
<td>GL_INT</td>
<td>((2^31 - 1))</td>
<td>((2^31 - 1)) * c - 1/2</td>
</tr>
<tr>
<td>GL_FLOAT</td>
<td>none</td>
<td>c</td>
</tr>
</tbody>
</table>

Return values are placed in memory as follows. If format is GL\_COLOR\_INDEX, GL\_STENCIL\_INDEX, GL\_DEPTH\_COMPONENT, GL\_RED, GL\_GREEN, GL\_BLUE, GL\_ALPHA, or GL\_LUMINANCE, a single value is returned and the data for the ith pixel in the jth row is placed in location \((j)\) width + i. GL\_RGB returns three values, GL\_RGBA returns four values, and GL\_LUMINANCE\_ALPHA returns two values for each pixel, with all values corresponding to a single pixel occupying contiguous space in pixels. Storage parameters set by gl\_Pixel\_Store, such as GL\_PACK\_SWAP\_BYTES and GL\_PACK\_LSB\_FIRST, affect the way that data is written into memory. See gl\_Pixel\_Store for a description.

### NOTES

Values for pixels that lie outside the window connected to the current GL context are undefined. If an error is generated, no change is made to the contents of pixels.

### ERRORS

GL\_INVALID\_ENUM is generated if format or type is not an accepted value.

GL\_INVALID\_VALUE is generated if either width or height is negative.

GL\_INVALID\_OPERATION is generated if format is GL\_COLOR\_INDEX and the color buffers store RGBA color components.
GL_INVALID_OPERATION is generated if format is GL_STENCIL_INDEX and there is no stencil buffer.

GL_INVALID_OPERATION is generated if format is GL_DEPTH_COMPONENT and there is no depth buffer.

GL_INVALID_OPERATION is generated if glReadPixels is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

glGet with argument GL_INDEX_MODE

SEE ALSO

"glCopyPixels", "glDrawPixels", "glPixelMap", "glPixelStore", "glPixelTransfer", "glReadBuffer"

NAME

glRect

− draw a rectangle

C SPECIFICATION

void glRectd( GLdouble x1, GLdouble y1, GLdouble x2, GLdouble y2 )
void glRectf( GLfloat x1, GLfloat y1, GLfloat x2, GLfloat y2 )
void glRecti( GLint x1, GLint y1, GLint x2, GLint y2 )
void glRects( GLshort x1, GLshort y1, GLshort x2, GLshort y2 )

PARAMETERS

x1, y1 Specify one vertex of a rectangle.
x2, y2 Specify the opposite vertex of the rectangle.

C SPECIFICATION

void glRectdv( const GLdouble *v1, const GLdouble *v2 )
void glRectfv( const GLfloat *v1, const GLfloat *v2 )
void glRectiv( const GLint *v1, const GLint *v2 )
void glRectsv( const GLshort *v1, const GLshort *v2 )

PARAMETERS

v1 Specifies a pointer to one vertex of a rectangle.
v2 Specifies a pointer to the opposite vertex of the rectangle.

DESCRIPTION

glRect supports efficient specification of rectangles as two corner points. Each rectangle command takes four arguments, organized either as two consecutive pairs of (x, y) coordinates, or as two pointers to arrays, each containing an (x, y) pair. The resulting rectangle is defined in the z=0 plane.

glRect(x1, y1, x2, y2) is exactly equivalent to the following sequence:

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Note that if the second vertex is above and to the right of the first vertex, the rectangle is constructed with a counterclockwise winding.

ERRORS

GL_INVALID_OPERATION is generated if glRect is called between a call to glBegin and the corresponding call to glEnd.

SEE ALSO

"glBegin", "glVertex"

NAME

glRenderMode

− set rasterization mode

C SPECIFICATION

GLint glRenderMode( GLenum mode )

PARAMETERS

mode Specifies the rasterization mode. Three values are accepted: GL_RENDER, GL_SELECT, and GL_FEEDBACK. The default value is GL_RENDER.

DESCRIPTION

glRenderMode sets the rasterization mode. It takes one argument, mode, which can assume one of three predefined values:

GL_RENDER Render mode. Primitives are rasterized, producing pixel fragments, which are written into the frame buffer. This is the normal mode and also the default mode.

GL_SELECT Selection mode. No pixel fragments are produced, and no change to the frame buffer contents is made. Instead, a record of the names of primitives that would have been drawn if the render mode was GL_RENDER is returned in a select buffer, which must be created (see "glSelectBuffer") before selection mode is entered.

GL_FEEDBACK Feedback mode. No pixel fragments are produced, and no change to the frame buffer contents is made. Instead, the coordinates and attributes of vertices that would have been drawn had the render mode been GL_RENDER is returned in a feedback buffer, which must be created (see "glFeedbackBuffer") before feedback mode is entered.

The return value of glRenderMode is determined by the render mode at the time glRenderMode is called, rather than by mode. The values returned for the three render modes are as follows:
---

**GL_RENDER**
Zero.

**GL_SELECT**
The number of hit records transferred to the select buffer.

**GL_FEEDBACK**
The number of values (not vertices) transferred to the feedback buffer.

Refer to the `glSelectBuffer` and `glFeedbackBuffer` reference pages for more details concerning selection and feedback operation.

**NOTES**
If an error is generated, `glRenderMode` returns zero regardless of the current render mode.

**ERRORS**
- **GL_INVALID_ENUM** is generated if `mode` is not one of the three accepted values.
- **GL_INVALID_OPERATION** is generated if `glSelectBuffer` is called while the render mode is `GL_SELECT`, or if `glSelectBuffer` is called with argument `GL_SELECT` before `glSelectBuffer` is called at least once.
- **GL_INVALID_OPERATION** is generated if `glFeedbackBuffer` is called while the render mode is `GL_FEEDBACK`, or if `glFeedbackBuffer` is called with argument `GL_FEEDBACK` before `glFeedbackBuffer` is called at least once.
- **GL_INVALID_OPERATION** is generated if `glRenderMode` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**
`glGet` with argument `GL_RENDER_MODE`

**SEE ALSO**
- `glSelectBuffer`, `glInitNames`, `glLoadName`, `glPassThrough`, `glPushName`, `glSelectBuffer`

---

**glRotate**

**NAME**
`glRotated`, `glRotatef` — multiply the current matrix by a rotation matrix

**C SPECIFICATION**

```c
void glRotated( GLdouble angle, GLdouble x, GLdouble y, GLdouble z )
void glRotatef( GLfloat angle, GLfloat x, GLfloat y, GLfloat z )
```

**PARAMETERS**

- **angle**
  Specifies the angle of rotation, in degrees.
- **x, y, z**
  Specify the x, y, and z coordinates of a vector, respectively.

**DESCRIPTION**

`glRotate` computes a matrix that performs a counterclockwise rotation of `angle` degrees about the vector from the origin through the point (`x, y, z`).

The current matrix (see "glMatrixMode") is multiplied by this rotation matrix, with the product replacing the current matrix. That is, if `M` is the current matrix and `R` is the translation matrix, then `M` is replaced with `M \times R`.

If the matrix mode is either `GL_MODELVIEW` or `GL_PROJECTION`, all objects drawn after `glRotate` are called are rotated. Use `glPushMatrix` and `glPopMatrix` to save and restore the unrotated coordinate system.

**ERRORS**

- **GL_INVALID_OPERATION** is generated if `glRotate` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**
`glGet` with argument `GL_MATRIX_MODE`
`glGet` with argument `GL_MODELVIEW_MATRIX`
`glGet` with argument `GL_PROJECTION_MATRIX`
`glGet` with argument `GL_TEXTURE_MATRIX`

**SEE ALSO**
- "glMatrixMode", "glMultMatrix", "glPushMatrix", "glScale", "glTranslate"

---

**glScale**

**NAME**
`glScaled`, `glScalef` — multiply the current matrix by a general scaling matrix

**C SPECIFICATION**

```c
void glScaled( GLdouble x, GLdouble y, GLdouble z )
void glScalef( GLfloat x, GLfloat y, GLfloat z )
```

**PARAMETERS**

- **x, y, z**
  Specify scale factors along the x, y, and z axes, respectively.

**DESCRIPTION**

`glScale` produces a general scaling along the x, y, and z axes. The three arguments indicate the desired scale factors along each of the three axes. The resulting matrix is
The current matrix (see "glmMatrixMode") is multiplied by this scale matrix, with the product replacing the current matrix. That is, if M is the current matrix and S is the scale matrix, then M is replaced with M o S.

If the matrix mode is either GL_MODELVIEW or GL_PROJECTION, all objects drawn after glScale is called are scaled. Use glPushMatrix and glPopMatrix to save and restore the unscaled coordinate system.

NOTES
If scale factors other than 1.0 are applied to the modelview matrix and lighting is enabled, automatic normalization of normals should probably also be enabled (glEnable and glDisable with argument GL_NORMALIZE).

ERRORS
GL_INVALID_OPERATION is generated if glScale is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_MATRIX_MODE
glGet with argument GL_MODELVIEW_MATRIX
glGet with argument GL_PROJECTION_MATRIX

SEE ALSO
"glmMatrixMode", "glmMultMatrix", "glmPushMatrix", "glmRotate", "glmTranslate"

---

The current matrix (see "glmMatrixMode") is multiplied by this scale matrix, with the product replacing the current matrix. That is, if M is the current matrix and S is the scale matrix, then M is replaced with M o S.

If the matrix mode is either GL_MODELVIEW or GL_PROJECTION, all objects drawn after glScale is called are scaled. Use glPushMatrix and glPopMatrix to save and restore the unscaled coordinate system.

NOTES
If scale factors other than 1.0 are applied to the modelview matrix and lighting is enabled, automatic normalization of normals should probably also be enabled (glEnable and glDisable with argument GL_NORMALIZE).

ERRORS
GL_INVALID_OPERATION is generated if glScale is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_MATRIX_MODE
glGet with argument GL_MODELVIEW_MATRIX
glGet with argument GL_PROJECTION_MATRIX

SEE ALSO
"glmMatrixMode", "glmMultMatrix", "glmPushMatrix", "glmRotate", "glmTranslate"

glScissor

NAME
glmScissor – define the scissor box

C SPECIFICATION
void glmScissor(GLint x, GLint y, GLsizei width, GLsizei height)

PARAMETERS
x, y Specify the lower left corner of the scissor box. Initially (0,0).
width, height Specify the width and height of the scissor box. When a GL context is first attached to a window, width and height are set to the dimensions of that window.

DESCRIPTION
The glmScissor routine defines a rectangle, called the scissor box, in window coordinates. The first two arguments, x and y, specify the lower left corner of the box. width and height specify the width and height of the box.

The scissor test is enabled and disabled using glEnable and glDisable with argument GL_SCISSOR_TEST. While the scissor test is enabled, only pixels that lie within the scissor box can be modified by drawing commands. Window coordinates have integer values at the shared corners of frame buffer pixels, so glmScissor(0,0,1,1) allows only the lower left pixel in the window to be modified, and glmScissor(0,0,0,0) disallows modification to all pixels in the window.

When the scissor test is disabled, it is as though the scissor box includes the entire window.

ERRORS
GL_INVALID_VALUE is generated if either width or height is negative.
GL_INVALID_OPERATION is generated if glmScissor is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_SCISSOR_BOX
glIsEnabled with argument GL_SCISSOR_TEST

SEE ALSO
"glEnable", "glViewport"

glmSelectBuffer

NAME
glmSelectBuffer – establish a buffer for selection mode values

C SPECIFICATION
void glmSelectBuffer( GLsizei size, GLuint *buffer )

PARAMETERS
size Specifies the size of buffer.
buffer Returns the selection data.

DESCRIPTION
glmSelectBuffer has two arguments: buffer is a pointer to an array of unsigned integers, and size indicates the size of the array. buffer returns values from the name stack (see "glmInitNames", "glmLoadName", "glmPushName") when the rendering mode is GL_SELECT (see "glmRenderMode"). glmSelectBuffer must be issued before selection mode is enabled, and it must not be issued while the rendering mode is GL_SELECT.

Selection is used by a programmer to determine which primitives are drawn into some region of a window. The region is defined by the current modelview and perspective matrices.

In selection mode, no pixel fragments are produced from rasterization. Instead, if a primitive intersects the clipping volume defined by the viewing frustum and the user-defined clipping planes, this primitive causes a selection hit. (With polygons, no hit occurs if the polygon is culled.) When a change is made to the name stack, or when glmRenderMode is called, a hit record is copied to buffer if any hits have occurred since the last such event (name stack change or glmRenderMode call). The hit record consists of the number of names in the name stack at the time of the event, followed by the minimum and maximum depth values of all vertices that hit since the previous event, followed by the name stack contents, bottom name first.
Returned depth values are mapped such that the largest unsigned integer value corresponds to window coordinate depth 1.0, and zero corresponds to window coordinate depth 0.0. An internal index into buffer is reset to zero whenever selection mode is entered. Each time a hit record is copied into buffer, the index is incremented to point to the cell just past the end of the block of names—that is, to the next available cell. If the hit record is larger than the number of remaining locations in buffer, as much data as can fit is copied, and the overflow flag is set. If the name stack is empty when a hit record is copied, that record consists of zero followed by the minimum and maximum depth values. Selection mode is exited by calling glRenderMode with an argument other than GL_SELECT. Whenever glRenderMode is called while the render mode is GL_SELECT, it returns the number of hit records copied to buffer, resets the overflow flag and the selection buffer pointer, and initializes the name stack to be empty. If the overflow bit was set when glRenderMode was called, a negative hit record count is returned.

NOTES
The contents of buffer are undefined until glRenderMode is called with an argument other than GL_SELECT.

glBegin/glEnd primitives and calls to glRasterPos can result in hits.

ERRORS
GL_INVALID_VALUE is generated if size is negative.
GL_INVALID_OPERATION is generated if glSelectBuffer is called while the render mode is GL_SELECT, or if glRenderMode is called with argument GL_SELECT before glSelectBuffer is called at least once.
GL_INVALID_OPERATION is generated if glSelectBuffer is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_NAME_STACK_DEPTH

SEE ALSO
"glFeedbackBuffer", "glInitNames", "glLoadName", "glPushName", "glRenderMode"

```c
void glShadeModel( GLenum mode )
```

NAME
glShadeModel — select flat or smooth shading

C SPECIFICATION
void glShadeModel( GLenum mode )

PARAMETERS
mode Specifies a symbolic value representing a shading technique. Accepted values are GL_FLAT and GL_SMOOTH. The default is GL_SMOOTH.

DESCRIPTION
GL primitives can have either flat or smooth shading. Smooth shading, the default, causes the computed colors of vertices to be interpolated as the primitive is rasterized, typically assigning different colors to each resulting pixel fragment. Flat shading selects the computed color of just one vertex and assigns it to all the pixel fragments generated by rasterizing a single primitive. In either case, the computed color of a vertex is the result of lighting, if lighting is enabled, or it is the current color at the time the vertex was specified, if lighting is disabled.

Flat and smooth shading are indistinguishable for points. Counting vertices and primitives from one starting when glBegin is issued, each flat−shaded line segment i is given the computed color of vertex +1, its second vertex. Counting similarly from one, each flat−shaded polygon is given the computed color of the vertex listed in the following table. This is the last vertex to specify the polygon in all cases except single polygons, where the first vertex specifies the flat−shaded color.

<table>
<thead>
<tr>
<th>primitive type of polygon</th>
<th>vertex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single polygon (tri)</td>
<td>1</td>
</tr>
<tr>
<td>Triangle strip</td>
<td>i + 2</td>
</tr>
<tr>
<td>Triangle fan</td>
<td>i + 2</td>
</tr>
<tr>
<td>Independent triangle</td>
<td>3i</td>
</tr>
<tr>
<td>Quad strip</td>
<td>2i + 2</td>
</tr>
<tr>
<td>Independent quad</td>
<td>4i</td>
</tr>
</tbody>
</table>

Flat and smooth shading are specified by glShadeModel with mode set to GL_FLAT and GL_SMOOTH, respectively.

ERRORS
GL_INVALID_ENUM is generated if mode is any value other than GL_FLAT or GL_SMOOTH.
GL_INVALID_OPERATION is generated if glShadeModel is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_SHADE_MODEL

SEE ALSO
"glBegin", "glColor", "glLight", "glLightModel"

```c
void glStencilFunc( GLenum func, GLint ref, GLuint mask )
```

NAME
glStencilFunc — set function and reference value for stencil testing

C SPECIFICATION
void glStencilFunc( GLenum func, GLint ref, GLuint mask )

PARAMETERS
func Specifies the test function. Eight tokens are valid: GL_NEVER, GL_LESS, GL_LEQUAL, GL_GREATER, GL_GEQUAL, GL_EQUAL, GL_NOTEQUAL, and GL_ALWAYS.
ref Specifies the reference value for the stencil test. ref is clamped to the range \([0, 2^n - 1]\).
where \( n \) is the number of bitplanes in the stencil buffer.

**DESCRIPTION**

Stenciling, like z-buffering, enables and disables drawing on a per-pixel basis. You draw into the stencil planes using GL, drawing primitives, then render geometry and images, using the stencil planes to mask out portions of the screen. Stenciling is typically used in multipass rendering algorithms to achieve special effects, such as decals, outlining, and constructive solid geometry rendering.

The stencil test conditionally eliminates a pixel based on the outcome of a comparison between the reference value and the value in the stencil buffer. The test is enabled by `glEnable` and `glDisable` with argument `GL_STENCIL`. Actions taken based on the outcome of the stencil test are specified with `glStencilOp`.

`func` is a symbolic constant that determines the stencil comparison function. It accepts one of eight values, shown below. `ref` is an integer reference value that is used in the stencil comparison. It is clamped to the range \([0,2^n-1]\), where \( n \) is the number of bitplanes in the stencil buffer. `mask` is bitwise ANDed with both the reference value and the stored stencil value, with the ANDed values participating in the comparison.

If `stencil` represents the value stored in the corresponding stencil buffer location, the following list shows the effect of each comparison function that can be specified by `func`. Only if the comparison succeeds is the pixel passed through to the next stage in the rasterization process (see “glStencilOp”).

All tests treat `stencil` values as unsigned integers in the range \([0,2^n-1]\), where \( n \) is the number of bitplanes in the stencil buffer.

Here are the values accepted by `func`:

- **GL_NEVER**: Always fails.
- **GL_LESS**: Passes if \((\text{ref} \& \text{mask}) < (\text{stencil} \& \text{mask})\).
- **GL_LEQUAL**: Passes if \((\text{ref} \& \text{mask}) \leq (\text{stencil} \& \text{mask})\).
- **GL_GREATER**: Passes if \((\text{ref} \& \text{mask}) > (\text{stencil} \& \text{mask})\).
- **GL_GEQUAL**: Passes if \((\text{ref} \& \text{mask}) \geq (\text{stencil} \& \text{mask})\).
- **GL_EQUAL**: Passes if \((\text{ref} \& \text{mask}) = (\text{stencil} \& \text{mask})\).
- **GL_NOTEQUAL**: Passes if \((\text{ref} \& \text{mask}) \neq (\text{stencil} \& \text{mask})\).
- **GL_ALWAYS**: Always passes.

**NOTES**

Initially, the stencil test is disabled. If there is no stencil buffer, no stencil modification can occur and it is as if the stencil test always passes.

**ERRORS**

- **GL_INVALID_ENUM** is generated if `func` is not one of the eight accepted values.
- **GL_INVALID_OPERATION** is generated if `glStencilFunc` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGet` with argument `GL_STENCIL_FUNC`
- `glGet` with argument `GL_STENCIL_VALUE_MASK`
- `glGet` with argument `GL_STENCIL_REF`
- `glGet` with argument `GL_STENCIL_BITS`

**SEE ALSO**


**glStencilMask**

**NAME**

`glStencilMask` — control the writing of individual bits in the stencil planes

**C SPECIFICATION**

```c
void glStencilMask( GLuint mask )
```

**PARAMETERS**

- `mask`: Specifies a bit mask to enable and disable writing of individual bits in the stencil planes. Initially, the mask is all ones.

**DESCRIPTION**

`glStencilMask` controls the writing of individual bits in the stencil planes. The least significant \( n \) bits of mask, where \( n \) is the number of bits in the stencil buffer, specify a mask. Wherever a one appears in the mask, the corresponding bit in the stencil buffer is made writable. Where a zero appears, the bit is write-protected. Initially, all bits are enabled for writing.

**ERRORS**

- **GL_INVALID_OPERATION** is generated if `glStencilMask` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGet` with argument `GL_STENCIL_WRITEMASK`
- `glGet` with argument `GL_STENCIL_BITS`

**SEE ALSO**

- “glColorMask”, “glDepthMask”, “glIndexMask”, “glStencilFunc”, “glStencilOp”

**glStencilOp**

**NAME**

`glStencilOp` — set stencil test actions

**C SPECIFICATION**

```c
void glStencilOp( GLenum fail, GLenum zfail, GLenum zpass )
```

- `fail`: Specifies the action taken if the stencil test fails.
- `zfail`: Specifies the action taken if the stencil test fails and the z-buffer test also fails.
- `zpass`: Specifies the action taken if the stencil test succeeds and the z-buffer test also succeeds.
The stencil test conditionally eliminates a pixel based on the outcome of a comparison between the pixel's color or depth buffers, and specifies what happens to the stencil buffer contents. The six possible actions are as follows:

- `GL_KEEP`: Keeps the current value.
- `GL_ZERO`: Sets the stencil buffer value to zero.
- `GL_REPLACE`: Sets the stencil buffer value to ref, as specified by `glStencilFunc`.
- `GL_INCR`: Increments the current stencil buffer value. Clamps to the maximum representable unsigned value.
- `GL_DECOR`: Decrements the current stencil buffer value. Clamps to zero.
- `GL_INVERT`: Bitwise inverts the current stencil buffer value.

Stenciling is typically used in multi-pass rendering algorithms to achieve special effects, such as decals, outlining, and constructive solid geometry rendering.

### SEE ALSO
- `glAlphaFunc`, `glBlendFunc`, `glDepthFunc`, `glEnable`, `glLogicOp`, `glStencilFunc`
- `glTexCoord`
PARAMETERS
target Specifies a texture environment. Must be GL_TEXTURE_ENV.
pname Specifies the symbolic name of a single−valued texture environment parameter. Must be one of GL_TEXTURE_ENV_MODE or GL_TEXTURE_ENV_COLOR.
param Specifies a single symbolic constant, or an RGBA color.

DESCRIPTION
The current texture coordinates are part of the data that is associated with polygon vertices. They are set with glTexCoord.

gTexCoord specifies texture coordinates in one, two, three, or four dimensions. glTexCoord1 sets the current texture coordinates to (s, 0, 0, 1); a call to glTexCoord2 sets them to (s, t, 0, 1). Similarly, glTexCoord3 specifies the texture coordinates as (s, t, r, q). If glTexCoord4 is called, the texture coordinates are set to (s, t, r, q), and three texture functions are defined: GL_MODULATE, GL_BLEND, and GL_DECAL. If glTexCoord4 is called, the texture coordinates are set to (s, t, r, q), and three texture functions are defined: GL_MODULATE, GL_BLEND, and GL_DECAL. If glTexCoord4 is called, the texture coordinates are set to (s, t, r, q), and three texture functions are defined: GL_MODULATE, GL_BLEND, and GL_DECAL. If glTexCoord4 is called, the texture coordinates are set to (s, t, r, q), and three texture functions are defined: GL_MODULATE, GL_BLEND, and GL_DECAL. If glTexCoord4 is called, the texture coordinates are set to (s, t, r, q), and three texture functions are defined: GL_MODULATE, GL_BLEND, and GL_DECAL.

NOTES
The current texture coordinates can be updated at any time. In particular, glTexCoord can be called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS
glGet with argument GL_CURRENT_TEXTURE_COORDS

SEE ALSO
‘glVertex’

gTexCoord

NAME
gTexCoord, glTexCoordi, glTexCoordfv, glTexCoordiv – set texture environment parameters

C SPECIFICATION
void glTexCoordNv(GLshort *v)  
void glTexCoord3Nv(const GLshort *v)  
void glTexCoord3fv(const GLfloat *v)  
void glTexCoord3iv(const GLint *v)  
void glTexCoord3dv(const GLdouble *v)  
void glTexCoord4Nv(const GLshort *v)  
void glTexCoord4fv(const GLfloat *v)  
void glTexCoord4iv(const GLint *v)  
void glTexCoord4dv(const GLdouble *v)  

PARAMETERS
target Specifies a texture environment. Must be GL_TEXTURE_ENV.
pname Specifies the symbolic name of a single−valued texture environment parameter. Must be one of GL_TEXTURE_ENV_MODE or GL_TEXTURE_ENV_COLOR.
param Specifies a single symbolic constant, one of GL_MODULATE, GL_DECAL, or GL_BLEND.
GL_INVALID_ENUM is generated when target or pname is not one of the accepted defined values, or when params should have a defined constant value (based on the value of pname) and does not.

GL_INVALID_OPERATION is generated if glTexEnv is called between a call to glBegin and the corresponding call to glEnd.

ASSOCIATED GETS

glGetTexEnv

SEE ALSO

gTexImage1D, glTexImage2D, glTexParameter

gTexGen

NAME

gTexGen, glTexGenf, glTexGeni, glTexGenfv, glTexGeniv — control the generation of texture coordinates

C SPECIFICATION

void glTexGeni (GLenum coord, GLenum pname, GLint param )
void glTexGenf (GLenum coord, GLenum pname, GLfloat param )
void glTexGen (GLenum coord, GLenum pname, const GLdouble *params )

PARAMETERS

coord Specifies a texture coordinate. Must be one of the following: GL_S, GL_T, GL_R, or GL_Q.

pname Specifies the symbolic name of the texture-coordinate generation function. Must be GL_TEXTURE_GEN_MODE.

param Specifies a single-valued texture generation parameter, one of GL_OBJ_ECT_LINEAR, GL_EYE_LINEAR, or GL_SPHERE_MAP.

C SPECIFICATION

void glTexGeni (GLenum coord, GLenum pname, const GLdouble *params )
void glTexGenf (GLenum coord, GLenum pname, const GLfloat *params )
void glTexGen (GLenum coord, GLenum pname, const GLdouble *params )

PARAMETERS

coord Specifies a texture coordinate. Must be one of the following: GL_S, GL_T, GL_R, or GL_Q.

pname Specifies the symbolic name of the texture-coordinate generation function or function parameters. Must be one of GL_TEXTURE_GEN_MODE, GL_OBJECT_LINEAR, or GL_EYE_LINEAR.

params Specifies a pointer to an array of texture generation parameters. If pname is GL_TEXTURE_GEN_MODE, then the array must contain a single symbolic constant, one of GL_OBJECT_LINEAR, GL_OBJECT_PLANE, or GL_EYE_LINEAR. Otherwise, params holds the coefficients for the texture-coordinate generation function specified by pname.

DESCRIPTION

gTexGen selects a texture-coordinate generation function or supplies coefficients for one of the functions. coord names one of the (s,t,r,q) texture coordinates, and it must be one of these symbols:

- GL_S
- GL_T
- GL_R
- GL_Q

pname must be one of three symbolic constants:

- GL_TEXTURE_GEN_MODE
- GL_OBJECT_LINEAR
- GL_EYE_LINEAR

If pname is GL_TEXTURE_GEN_MODE, then params chooses a mode, one of GL_OBJECT_LINEAR, GL_EYE_LINEAR, or GL_SPHERE_MAP. If pname is either GL_OBJECT_ECT_PLAN or GL_EYE_LINEAR, params contains coefficients for the corresponding texture generation function. If the texture generation function is GL_OBJECT_LINEAR, the function

\[ g = p_x x + p_y y + p_z z + p_w w \]

is used, where \( g \) is the value computed for the coordinate named in coord, \( p_x, p_y, p_z, \text{ and } p_w \) are the four values supplied in params, and \( x_0, y_0, z_0, \text{ and } w_0 \) are the object coordinates of the vertex. This function can be used to texture-map terrain using sea level as a reference plane (defined by \( p_1, p_2, p_3, \text{ and } p_4 \)).

The altitude of a terrain vertex is computed by the GL_OBJECT_LINEAR coordinate generation function as its distance from sea level; that altitude is used to index the texture image to map white snow onto peaks and green grass onto foothills, for example.

If the texture generation function is GL_EYE_LINEAR, the function

\[ g = p_x x + p_y y + p_z z + p_w w \]

is used, where \( g \) is the value computed for the coordinate named in coord, \( p_x, p_y, p_z, \text{ and } p_w \) are the four values supplied in params, and \( x_0, y_0, z_0, \text{ and } w_0 \) are the eye coordinates of the vertex, \( p_1, p_2, p_3, \text{ and } p_4 \) are the values supplied in params, and \( M \) is the modelview matrix when glTexGen is invoked. If \( M \) is poorly conditioned or singular, texture coordinates generated by the resulting function may be inaccurate or undefined.

Note that the values in params define a reference plane in eye coordinates. The modelview matrix that is applied to them may not be the same one in effect when the polygon vertices are transformed. This function establishes a field of texture coordinates that can produce dynamic contour lines on moving objects.

If pname is GL_SPHERE_MAP and coord is either GL_S or GL_T, s and t texture coordinates are generated as follows. Let \( u \) be the unit vector pointing from the origin to the polygon vertex (in eye coordinates). Let \( n \) be the current normal, after transformation to eye coordinates. Let \( f = ( f_x f_y f_z ) \) be the reflection vector such that

\[ f = u - 2 n' n' T u \]

Finally, let

\[ m = 2 \sqrt{f_x^2 + f_y^2 + (f_z + 1)^2} \]

Then the values assigned to the s and t texture coordinates are

\[ t = \frac{f_z + 1}{m} \]
\[ s = \frac{f_y}{m} \]
A texture-coordinate generation function is enabled or disabled using `glEnable` or `glDisable` with one of the symbolic texture-coordinate names: `GL_TEXTURE_GEN_S`, `GL_TEXTURE_GEN_T`, `GL_TEXTURE_GEN_R`, or `GL_TEXTURE_GEN_Q` as the argument. When enabled, the specified texture coordinate is computed according to the generating function associated with that coordinate. When disabled, subsequent vertices take the specified texture coordinate from the current set of texture coordinates. Initially, all texture generation functions are set to `GL_EYE_LINEAR` and are disabled. Both s plane equations are (1,0,0,0), both t plane equations are (0,1,0,0), and all r and q plane equations are (0,0,0,0).

**ERRORS**

- `GL_INVALID_ENUM` is generated when coord or pname is not an accepted defined value, or when pname is `GL_TEXTURE_GEN_MODE` and params is not an accepted defined value.
- `GL_INVALID_ENUM` is generated when pname is `GL_TEXTURE_GEN_MODE`, params is `GL_SPHERE_MAP`, and coord is either `GL_R` or `GL_Q`.
- `GL_INVALID_OPERATION` is generated if `glTexGen` is called between a call to `glBegin` and the corresponding call to `glEnd`.

**ASSOCIATED GETS**

- `glGetTexGen` with argument `GL_TEXTURE_GEN_S`
- `glGetTexGen` with argument `GL_TEXTURE_GEN_T`
- `glGetTexGen` with argument `GL_TEXTURE_GEN_R`
- `glGetTexGen` with argument `GL_TEXTURE_GEN_Q`

**SEE ALSO**

- `glTexEnv`, `glTexImage1D`, `glTexImage2D`, `glTexParameter`
- `glTexImage1D` — specify a one-dimensional texture image

**NAME**

- `glTexImage1D` — specify a one-dimensional texture image

**C SPECIFICATION**

```c
void glTexImage1D(GLenum target, GLint level, GLint components, GLsizei width, GLint border, GLenum format, GLenum type, const GLvoid *pixels)
```

**PARAMETERS**

- `target` Specifies the target texture. Must be `GL_TEXTURE_1D`.
- `level` Specifies the level−of−detail number. Level 0 is the base image level. Level n is then mipmap reduction image.
- `components` Specifies the number of color components in the texture. Must be 1, 2, 3, or 4.
- `width` Specifies the width of the texture image. Must be $2^n + 2$ (border) for some integer n. The height of the texture image is 1.
- `border` Specifies the width of the border. Must be either 0 or 1.

**DESCRIPTION**

Texturing maps a portion of a specified texture image onto each graphical primitive for which texturing is enabled. One-dimensional texturing is enabled and disabled using `glEnable` and `glDisable` with argument `GL_TEXTURE_1D`.

Texture images are defined with `glTexImage1D`. The arguments describe the parameters of the texture image, such as width, width of the border, level−of−detail number (see `glTexParameteri`), and number of color components provided. The last three arguments describe the way the image is represented in memory, and they are identical to the pixel formats used for `glDrawPixels`.

Data is read from pixels as a sequence of signed or unsigned bytes, shorts, or longs, or single−precision floating−point values, depending on type. These values are grouped into sets of one, two, three, or four values, depending on format, to form elements. If `type` is `GL_BITMAP`, the data is considered a string of unsigned bytes (and format must be `GL_COLOR_INDEX`). Each data byte is treated as eight 1−bit elements, with bit ordering determined by the corresponding call to `glPixelStore`.

- `pixels` Specifies a pointer to the image data in memory.

- `format` Specifies the format of the pixel data. The following symbolic values are accepted:
  - `GL_COLOR_INDEX`
  - `GL_RED`
  - `GL_GREEN`
  - `GL_BLUE`
  - `GL_ALPHA`
  - `GL_RGB`
  - `GL_RGBA`
  - `GL_LUMINANCE`
  - `GL_RGB_ALPHA`

- `type` Specifies the data type of the pixel data. The following symbolic values are accepted:
  - `GL_UNSIGNED_BYTE`
  - `GL_BYTE`
  - `GL_SHORT`
  - `GL_UNSIGNED_SHORT`
  - `GL_UNSIGNED_INT`
  - `GL_INT`
  - `GL_FLOAT`

- `width` Specifies the width of the texture image. Must be $2^n + 2$ (border) for some integer n. The height of the texture image is 1.

**SEE ALSO**

- `glTexImage2D`, `glTexParameter`
to the range [0,1] (see "glPixelTransfer").

GL_RGBA
Each element is a complete RGBA element. It is converted to floating point. Each component is then multiplied by the signed scale factor GL_c_SCALE, added to the signed bias GL_c_BIAS, and clamped to the range [0,1] (see "glPixelTransfer").

GL_LUMINANCE
Each element is a single luminance value. It is converted to floating point, then assembled into an RGBA element by replicating the luminance value three times for red, green, and blue and attaching 1.0 for alpha. Each component is then multiplied by the signed scale factor GL_c_SCALE, added to the signed bias GL_c_BIAS, and clamped to the range [0,1] (see "glPixelTransfer").

GL_LUMINANCE_ALPHA
Each element is a luminance/alpha pair. It is converted to floating point, then assembled into an RGBA element by replicating the luminance value three times for red, green, and blue. Each component is then multiplied by the signed scale factor GL_c_SCALE, added to the signed bias GL_c_BIAS, and clamped to the range [0,1] (see "glPixelTransfer").

A texture image can have up to four components per texture element, depending on components. A one−component texture image uses only the red component of the RGBA color extracted from pixels. A two−component image uses the R and A values. A three−component image uses the R, G, and B values. A four−component image uses all of the RGBA components.

NOTES
Texturing has no effect in color index mode.

The texture image can be represented by the same data formats as the pixels in `glDrawPixels` command, except that `GL_STENCIL_INDEX` and `GL_DEPTH_COMPONENT` cannot be used. `glPixelStore` and `glPixelTransfer` modes affect texture images in exactly the same way they affect `glDrawPixels`.

A texture image with zero width indicates the null texture. If the null texture is specified for level−of−detail 0, it is as if texturing were disabled.

ERRORS
`GL_INVALID_ENUM` is generated when target is not `GL_TEXTURE_2D`.

`GL_INVALID_ENUM` is generated when format is not an accepted format constant. Format constants other than `GL_STENCIL_INDEX` and `GL_DEPTH_COMPONENT` are accepted.

`GL_INVALID_ENUM` is generated when type is not a type constant.

`GL_INVALID_ENUM` is generated if level is less than zero or greater than `log2(max)` where `max` is the returned value of `GL_MAX_TEXTURE_SIZE`.

`GL_INVALID_VALUE` is generated if components is not 1, 2, 3, or 4.

`GL_INVALID_VALUE` is generated if width is less than zero or greater than `2 + GL_MAX_TEXTURE_SIZE`, or if it cannot be represented as `2^n + 2*border` for some integer value of n.

`GL_INVALID_VALUE` is generated if border is not 0 or 1.

`GL_INVALID_OPERATION` is generated if `glTexImage2D` is called between a call to `glBegin` and the corresponding call to `glEnd`.

ASSOCIATED GETS
`glGetTexImage`

`glTexImage2D` with argument `GL_TEXTURE_2D`

SEE ALSO
`glDrawPixels`, `glFog`, `glPixelStore`, `glPixelTransfer`, `glTexEnv`, `glTexImage2D`, `glTexParameter`

C SPECIFICATION
void `glTexImage2D` ( GLenum target, GLint level, GLint components, GLsizei width, GLsizei height, GLint border, GLenum format, GLenum *pixels )

PARAMETERS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>target</td>
<td>Specifies the target texture. Must be <code>GL_TEXTURE_2D</code>.</td>
</tr>
<tr>
<td>level</td>
<td>Specifies the level−of−detail number. Level 0 is the base image level. Level n is the n−th mipmap reduction image.</td>
</tr>
<tr>
<td>components</td>
<td>Specifies the number of color components in the texture. Must be 1, 2, 3, or 4.</td>
</tr>
<tr>
<td>width</td>
<td>Specifies the width of the texture image. Must be <code>2^n + 2*border</code> for some integer n.</td>
</tr>
<tr>
<td>height</td>
<td>Specifies the height of the texture image. Must be <code>2^n + 2*border</code> for some integer n.</td>
</tr>
<tr>
<td>border</td>
<td>Specifies the width of the border. Must be either 0 or 1.</td>
</tr>
<tr>
<td>format</td>
<td>Specifies the format of the pixel data. The following symbolic values are accepted: <code>GL_COLOR_INDEX</code>, <code>GL_RED</code>, <code>GL_GREEN</code>, <code>GL_BLUE</code>, <code>GL_ALPHA</code>, <code>GL_RGB</code>, <code>GL_RGBA</code>, <code>GL_LUMINANCE</code>, and <code>GL_LUMINANCE_ALPHA</code>.</td>
</tr>
<tr>
<td>type</td>
<td>Specifies the data type of the pixel data. The following symbolic values are accepted: <code>GL_UNSIGNED_BYTE</code>, <code>GL_BYTE</code>, <code>GL_BITMAP</code>, <code>GL_UNSIGNED_SHORT</code>, <code>GL_SHORT</code>, <code>GL_UNSIGNED_INT</code>, <code>GL_INT</code>, and <code>GL_FLOAT</code>.</td>
</tr>
<tr>
<td>pixels</td>
<td>Specifies a pointer to the image data in memory.</td>
</tr>
</tbody>
</table>

DESCRIPTION
Texturing maps a portion of a specified texture image onto each graphical primitive for which texturing is enabled. Two−dimensional texturing is enabled and disabled using `glEnable` and `glDisable` with argument `GL_TEXTURE_2D`.

Texturing images are defined with `glTexImage2D`. The arguments describe the parameters of the texture image, such as height, width, width of the border, level−of−detail number (see "glTexParameter"), and number of color components provided. The last three arguments describe the way the image is represented in memory, and they are identical to the pixel formats used for `glDrawPixels`.

Data is read from pixels as a sequence of signed or unsigned bytes, shorts, or longs, or single−precision floating−point values, depending on type. These values are grouped into sets of one, two, three, or four values, depending on format, to form elements. If `glColor_BTMAP`, the data is considered as a string of unsigned bytes (and format must be `GL_COLOR_INDEX`). Each data byte is treated as eight 1−bit elements, with bit ordering determined by `GL_UNPACK_LSB_FIRST` (see "glPixelStore").
GL_COLOR_INDEX

Each element is a single value, a color index. It is converted to fixed point (with an unspecified number of zero bits to the right of the binary point), shifted left or right depending on the value and sign of GL_INDEX_OFFSET, and added to GL_INDEX_SHIFT. The resulting index is converted to a set of color components using the \texttt{glPixelMapI} function.

GL_INDEX_OFFSET and GL_INDEX_SHIFT are commands, and \texttt{glPixelMapI} is generated when \texttt{format} is not \texttt{GL_COLOR_INDEX}.

GL_INDEX_OFFSET

Each element is a single component. It is converted to floating point and assembled into an RGBA element by attaching 0.0 for green and blue, and 1.0 for alpha. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

GL_blue

Each element is a single green component. It is converted to floating point and assembled into an RGBA element by attaching 0.0 for red and blue, and 1.0 for alpha. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

GL_ALPHA

Each element is a single red component. It is converted to floating point and assembled into an RGBA element by attaching 0.0 for red, green, and blue, and 1.0 for alpha. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

GL_RGB

Each element is an RGB triple. It is converted to floating point and assembled into an RGBA element by attaching 0.0 for red, green, and blue, and 1.0 for alpha. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

GL_RGBA

Each element is a complete RGBA element. It is converted to floating point. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

GL_LUMINANCE

Each element is a single luminance value. It is converted to floating point, then assembled into an RGBA element by replicating the luminance value three times for red, green, and blue, and attaching 1.0 for alpha. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

GL_LUMINANCE_ALPHA

Each element is a luminance/alpha pair. It is converted to floating point, then assembled into an RGBA element by replicating the luminance value three times for red, green, and blue, and attaching 1.0 for alpha. Each component is then multiplied by the signed scale factor \texttt{GL_c_SCALE}, added to the signed bias \texttt{GL_c_BIAS}, and clamped to the range [0,1].

Please refer to the \texttt{glDrawPixels} reference page for a description of the acceptable values for \texttt{type} parameter. A texture image can have up to four components per texture element, depending on components. A one-component texture image uses only the red component of the RGBA color extracted from pixels. A two-component image uses the R and A values. A three-component image uses the R, G, and B values. A four-component image uses all of the RGBA components.

GL_INVALID_ENUM is generated when target is not \texttt{GL_TEXTURE_2D}.

GL_INVALID_OPERATION is generated if \texttt{type} is not an accepted format constant. Format constants other than \texttt{GL_STENCIL_INDEX} and \texttt{GL_DEPTH_COMPONENT} are accepted.

GL_INVALID_OPERATION is generated if \texttt{type} is \texttt{GL_BITMAP} and \texttt{format} is not \texttt{GL_COLOR_INDEX}.

GL_INVALID_OPERATION is generated if \texttt{level} is less than zero or greater than \texttt{GL_MAX_TEXTURE_SIZE}, where \texttt{max} is the returned value of \texttt{GL_MAX_TEXTURE_SIZE}.

GL_INVALID_OPERATION is generated if components is not 1, 2, 3, or 4.

GL_INVALID_OPERATION is generated if \texttt{width} or \texttt{height} is less than zero or greater than 2 \texttt{GL_max GLints}, or if either cannot be represented as \texttt{2^k} (border) for some integer value of \texttt{k}.

GL_INVALID_OPERATION is generated if \texttt{border} is not 0 or 1.

GL_INVALID_OPERATION is generated if \texttt{glTexImage2D} is called between a call to \texttt{glBegin} and the corresponding call to \texttt{glEnd}.

ASSOCIATED GETS

\texttt{glTexImage2D} \texttt{glIsEnabled} with argument \texttt{GL_TEXTURE_2D}

SEE ALSO

\texttt{glDrawPixels}, \texttt{glFog}, \texttt{glPixelStore}, \texttt{glPixelTransfer}, \texttt{glTexImage}, \texttt{glTexEnv}, \texttt{glTexImage2D}, \texttt{glTexGen}, \texttt{glTexImage1D}, \texttt{glTexParameter}

\texttt{glTexParameter}

NAME

\texttt{glTexParameter}, \texttt{glTexParameter}, \texttt{glTexParameter}, \texttt{glTexParameter} = set texture parameters

C SPECIFICATION

void \texttt{glTexParameter} ( \texttt{GLenum target, GLenum pname, GLfloat param} )
void \texttt{glTexParameter} ( \texttt{GLenum target, GLenum pname, GLint param} )

PARAMETERS

\texttt{target} Specifies the target texture, which must be \texttt{GL_TEXTURE_2D} or
GL_LINEAR_MIPMAP_NEAREST
Chooses the mipmap that most closely matches the size of the pixel being textured and uses the GL_NEAREST criterion (a weighted average of the four texture elements that are closest to the center of the pixel) to produce a texture value.

GL_NEAREST_MIPMAP_LINEAR
Chooses the two mipmaps that most closely match the size of the pixel being textured and uses the GL_LINEAR criterion (a weighted average of the four texture elements that are closest to the center of the pixel) to produce a texture value from each mipmap. The final texture value is a weighted average of those two values.

GL_LINEAR_MIPMAP_LINEAR
Chooses the two mipmaps that most closely match the size of the pixel being textured and uses the GL_LINEAR criterion (a weighted average of the four texture elements that are closest to the center of the pixel) to produce a texture value. As more texture elements are sampled in the minification process, fewer aliasing artifacts will be apparent. While the GL_NEAREST and GL_LINEAR minification functions can be faster than the other two, they sample only one or four texture elements to determine the texture value of the pixel being rendered and can produce moire patterns or ragged transitions. The default value of GL_TEXTURE_MIN_FILTER is GL_LINEAR_MIPMAP_LINEAR.

GL_TEXTURE_MAG_FILTER
The texture magnification function is used when the pixel being textured maps to an area less than or equal to one texture element. It sets the texture magnification function to either of the following:

GL_LINEAR
Returns the value of the texture element that is nearest (in Manhattan distance) to the center of the pixel being textured. GL_LINEAR returns the weighted average of the four texture elements that are closest to the center of the pixel being textured. These can include border texture elements, depending on the values of GL_TEXTURE_WRAP_S and GL_TEXTURE_WRAP_T, and on the exact mapping.

GL_NEAREST
Returns the value of the texture element that is nearest (in Manhattan distance) to the center of the pixel being textured. GL_NEAREST is generally faster than GL_LINEAR, but it can produce texture images with sharper edges because the transition between texture elements is not as smooth. The default value of GL_TEXTURE_MAG_FILTER is GL_LINEAR.

GL_TEXTURE_WRAP_S
Sets the wrap parameter for texture coordinate s to either GL_CLAMP or GL_REPEAT. GL_CLAMP causes s coordinates to be clamped to the range [0,1] and is useful for preventing wrapping artifacts when mapping a single image onto an object. GL_REPEAT causes the integer part of the s coordinate to be ignored; the GL uses only the fractional part, thereby creating a repeating pattern. Border texture elements are accessed only if wrapping is set to GL_CLAMP. Initially, GL_TEXTURE_WRAP_S is set to GL_CLAMP.

GL_TEXTURE_WRAP_T
Sets the wrap parameter for texture coordinate t to either GL_CLAMP or GL_REPEAT. See the discussion under GL_TEXTURE_WRAP_S. Initially, GL_TEXTURE_WRAP_T is set to GL_REPEAT.

GL_TEXTURE_BORDER_COLOR
Sets a border color. params contains four values that comprise the RGBA color of the texture border. Integer color components are interpreted linearly such that the most positive integer maps to 1.0, and the most negative integer maps to −1.0. The values are clamped to the range [0.0,1.0] when they are specified. Initially, the border color is (0, 0, 0, 0).

NOTES

Texture mapping is a technique that applies an image onto an object's surface as if the image were a decal or cellophane shrink-wrap. The image is created in texture space, with an isometric coordinate system. A texture is a one- or two-dimensional image and a set of parameters that determine how samples are derived from the image.

The texture minifying function is used whenever the pixel being textured maps to an area larger than one texture element. There are six defined minifying functions. Two of them use the nearest one or nearest four texture elements to compute the texture value. The other uses four mipmaps.

A mipmap is an ordered set of arrays representing the same image at progressively lower resolutions. If the texture has dimensions 2^n x 2^m there are max(n, m) + 1 mipmaps. The first mipmap is the original texture, with dimensions 2^n x 2^m. Each subsequent mipmap has dimensions 2^(k − 2^l) x 2^(m − 2^l) where 2^k is the dimensions of the previous mipmap, until either k = 0 or m = 0. At that point, subsequent mipmaps have dimensions 1 x 1 until the final mipmap, which has dimension 1 x 1. Mipmaps are defined using glTexImage1D or glTexImage2D with the level-of-detail argument indicating the order of the mipmaps. Level 0 is the original texture; level max(n, m) is the final 1 x 1 mipmap.

Supplies a function for minifying the texture as one of the following:

GL_NEAREST
Returns the value of the texture element that is closest to the center of the pixel being textured. This can include border texture elements, depending on the values of GL_TEXTURE_WRAP_S and GL_TEXTURE_WRAP_T, and on the exact mapping.

GL_LINEAR
Returns the weighted average of the four texture elements that are closest to the center of the pixel being textured. This can include border texture elements, depending on the values of GL_TEXTURE_WRAP_S and GL_TEXTURE_WRAP_T.

GL_NEAREST_MIPMAP_NEAREST
Chooses the mipmap that most closely matches the size of the pixel being textured and uses the GL_NEAREST criterion (a weighted average of the four texture elements that are closest to the center of the pixel) to produce a texture value.

GL_NEAREST_MIPMAP_LINEAR
Chooses the two mipmaps that most closely match the size of the pixel being textured and uses the GL_NEAREST criterion (a weighted average of the four texture elements that are closest to the center of the pixel) to produce a texture value from each mipmap. The final texture value is a weighted average of those two values.

GL_LINEAR_MIPMAP_LINEAR
Chooses the two mipmaps that most closely match the size of the pixel being textured and uses the GL_LINEAR criterion (a weighted average of the four texture elements that are closest to the center of the pixel) to produce a texture value. As more texture elements are sampled in the minification process, fewer aliasing artifacts will be apparent. While the GL_NEAREST and GL_LINEAR minification functions can be faster than the other two, they sample only one or four texture elements to determine the texture value of the pixel being rendered and can produce moire patterns or ragged transitions. The default value of GL_TEXTURE_MIN_FILTER is GL_LINEAR_MIPMAP_LINEAR.

GL_TEXTURE_MAG_FILTER
The texture magnification function is used when the pixel being textured maps to an area less than or equal to one texture element. It sets the texture magnification function to either GL_LINEAR or GL_NEAREST.

GL_TEXTURE_WRAP_S
Sets the wrap parameter for texture coordinate s to either GL_CLAMP or GL_REPEAT. GL_CLAMP causes s coordinates to be clamped to the range [0,1] and is useful for preventing wrapping artifacts when mapping a single image onto an object. GL_REPEAT causes the integer part of the s coordinate to be ignored; the GL uses only the fractional part, thereby creating a repeating pattern. Border texture elements are accessed only if wrapping is set to GL_CLAMP. Initially, GL_TEXTURE_WRAP_S is set to GL_CLAMP.

GL_TEXTURE_WRAP_T
Sets the wrap parameter for texture coordinate t to either GL_CLAMP or GL_REPEAT. See the discussion under GL_TEXTURE_WRAP_S. Initially, GL_TEXTURE_WRAP_T is set to GL_REPEAT.

GL_TEXTURE_BORDER_COLOR
Sets a border color. params contains four values that comprise the RGBA color of the texture border. Integer color components are interpreted linearly such that the most positive integer maps to 1.0, and the most negative integer maps to −1.0. The values are clamped to the range [0.0,1.0] when they are specified. Initially, the border color is (0, 0, 0, 0).
Suppose texturing is enabled (by calling glEnable with argument GL_TEXTURE_1D or GL_TEXTURE_2D) and GL_TEXTURE_MIN_FILTER is set to one of the functions that requires a mipmap. If either the dimensions of the texture images currently defined (with previous calls to glTexImage1D or glTexImage2D) do not follow the proper sequence for mipmaps (described above), or there are fewer texture images defined than are needed, or the set of texture images have differing numbers of texture components, then it is as if texture mapping were disabled.

Linear filtering accesses the four nearest texture elements only in 2-D textures. In 1-D textures, linear filtering accesses the two nearest texture elements.

**ERRORS**

GL_INVALID_ENUM is generated when target or pname is not one of the accepted defined values, or when params should have a defined constant value (based on the value of pname) and does not.

**ASSOCIATED GETS**

glGet with argument GL_TEXTURE_1D or GL_TEXTURE_2D

**SEE ALSO**

'glTexImage1D', 'glTexImage2D', 'glTexParameteri'

---

The current matrix (see "glMatrixMode") is multiplied by this translation matrix, with the product replacing the current matrix. That is, if M is the current matrix and T is the translation matrix, then M is replaced with M o T.

If the matrix mode is either GL_MODELVIEW or GL_PROJECTION, all objects drawn after glTranslatef is called are translated. Use glPushMatrix and glPopMatrix to save and restore the untranslated coordinate system.

**ERRORS**

GL_INVALID_OPERATION is generated if glTranslatef is called between a call to glBegin and the corresponding call to glEnd.

**ASSOCIATED GETS**

glGet with argument GL_MODELVIEW_MATRIX

**SEE ALSO**

'glMatrixMode', 'glMultMatrix', 'glPushMatrix', 'glRotate', 'glScale'

---

**glVertex**

**NAME**

glTranslated, glTranslatef – multiply the current matrix by a translation matrix

**C SPECIFICATION**

```c
void glVertex3d( GLdouble x, GLdouble y, GLdouble z )
void glVertex3f( GLfloat x, GLfloat y, GLfloat z )
void glVertex3i( GLint x, GLint y, GLint z )
void glVertex3s( GLshort x, GLshort y, GLshort z )
```

**PARAMETERS**

x, y, z Specify the x, y, and z coordinates of a vertex.

**DESCRIPTION**

glTranslatef moves the coordinate system origin to the point specified by (xyz). The translation vector is used to compute a 4×4 translation matrix:

```plaintext
  0 0 0 1
  0 1 0 0
  0 0 1 0
  0 0 0 1
```
void glVertex2dv( const GLdouble* v )
void glVertex2fv( const GLfloat* v )
void glVertex2iv( const GLint* v )
void glVertex2sv( const GLshort* v )
void glVertex3dv( const GLdouble* v )
void glVertex3fv( const GLfloat* v )
void glVertex3iv( const GLint* v )
void glVertex3sv( const GLshort* v )
void glVertex4dv( const GLdouble* v )
void glVertex4fv( const GLfloat* v )
void glVertex4iv( const GLint* v )
void glVertex4sv( const GLshort* v )

PARAMETERS

v Specifies a pointer to an array of two, three, or four elements. The elements of a
two-element array are x and y; of a three-element array, x, y, and z; and of a
four-element array, x, y, z, and w.

DESCRIPTION
glVertex commands are used within glBegin/glEnd pairs to specify point, line, and polygon vertices.
The current color, normal, and texture coordinates are associated with the vertex when
 glVertex is called.
When only x and y are specified, z defaults to 0.0 and w defaults to 1.0. When x, y, and z are specified, w
defaults to 1.0.

NOTES
Invoking glVertex outside of a glBegin/glEnd pair results in undefined behavior.

SEE ALSO
‘glNormal’, ‘glRect’, ‘glTexCoord’

glViewport

NAME
glViewport – set the viewport

C SPECIFICATION
void glViewport( GLint x, GLint y, GLsizei width, GLsizei height )

PARAMETERS

x, y Specify the lower left corner of the viewport rectangle, in pixels. The default is (0,0).
width, height Specify the width and height, respectively, of the viewport. When a GL context is first
attached to a window, width and height are set to the dimensions of that window.

DESCRIPTION
glViewport specifies the affine transformation of x and y from normalized device coordinates to
window coordinates. Let (xnd, ynd) be normalized device coordinates. Then the window coordinates (xw,
yw) are computed as follows:

\[
x_w = (x_{nd} + 1) \left( \frac{\text{width}}{2} \right) + x
\]

\[
y_w = (y_{nd} + 1) \left( \frac{\text{height}}{2} \right) + y
\]

Viewport width and height are silently clamped to a range that depends on the implementation. This
range is queried by calling glGet with argument GL_MAX_VIEWPORT_DIMS.

ERRORS
GL_INVALID_VALUE is generated if either width or height is negative.
GL_INVALID_OPERATION is generated if glViewport is called between a call to glBegin and the
 corresponding call to glEnd.

ASSOCIATED GETS
get with argument GL_VIEWPORT
get with argument GL_MAX_VIEWPORT_DIMS

SEE ALSO
‘glDepthRange’

Chapter 6
GLU Reference Pages
This chapter contains the reference pages, in alphabetical order, for all the routines comprising the
OpenGL Utility Library (GLU).

glBeginCurve

NAME
glBeginCurve, glEndCurve – delimit a NURBS curve definition
C SPECIFICATION

```c
void gluBeginCurve(GLUnurbsObj *nobj)
void gluEndCurve(GLUnurbsObj *nobj)
```

PARAMETERS

- `nobj` Specifies the NURBS object (created with `gluNewNurbsRenderer`).

DESCRIPTION

Use `gluBeginCurve` to mark the beginning of a NURBS curve definition. After calling `gluBeginCurve`, make one or more calls to `gluNurbsCurve` to define the attributes of the curve. Exactly one of the calls to `gluNurbsCurve` must have a curve type of `GL_MAP1_VERTEX_3` or `GL_MAP1_VERTEX_4`. To mark the end of the NURBS curve definition, call `gluEndCurve`.

OpenGL evaluators are used to render the NURBS curve as a series of line segments. Evaluator state is preserved during rendering with `glPushAttrib(GL_EVAL_BIT)` and `glPopAttrib()`. See the `"glPushAttrib"` reference page for details on exactly what state these calls preserve.

EXAMPLE

The following commands render a textured NURBS curve with normals; texture coordinates and normals are also specified as NURBS curves:

```c
gluBeginCurve(nobj);    gluNurbsCurve(nobj, ..., GL_MAP1_TEXTURE_COORD_2);    gluNurbsCurve(nobj, ..., GL_MAP1_NORMAL);    gluNurbsCurve(nobj, ..., GL_MAP1_VERTEX_4);    gluEndCurve(nobj);
```

SEE ALSO

- "gluBeginSurface", "gluBeginTrim", "gluNewNurbsRenderer", "gluNurbsCurve", "glPopAttrib", "glPushAttrib"

### gluBeginPolygon

NAME

`gluBeginPolygon`, `gluEndPolygon` — delimit a polygon description

C SPECIFICATION

```c
void gluBeginPolygon(GLUtriangulatorObj *tobj)
void gluEndPolygon(GLUtriangulatorObj *tobj)
```

PARAMETERS

- `tobj` Specifies the tessellation object (created with `gluNewTess`).

DESCRIPTION

Use `gluBeginPolygon` to mark the beginning of a NURBS surface definition. After calling `gluBeginPolygon`, make one or more calls to `gluNurbsSurface` to define the attributes of the surface. Exactly one of these calls to `gluNurbsSurface` must have a surface type of `GL_MAP2_VERTEX_3` or `GL_MAP2_VERTEX_4`. To mark the end of the NURBS surface definition, call `gluEndSurface`.

Trimming of NURBS surfaces is supported with `gluBeginTrim`, `gluPwlCurve`, `gluNurbsCurve`, and `gluEndTrim`. Refer to the `gluBeginTrim` reference page for details.

OpenGL evaluators are used to render the NURBS surface as a set of polygons. Evaluator state is preserved during rendering with `glPushAttrib(GL_EVAL_BIT)` and `glPopAttrib()`. See the "glPushAttrib" reference page for details on exactly what state these calls preserve.
**EXAMPLE**

The following commands render a textured NURBS surface with normals; the texture coordinates and normals are also described as NURBS surfaces:

```c
    gluBeginSurface(nobj);    gluNurbsSurface(nobj, ... , GL_MAP2_TEXTURE_COORD_2);    gluNurbsSurface(nobj, ... , GL_MAP2_NORMAL);    gluNurbsSurface(nobj, ... , GL_MAP2_VERTEX_4);    gluEndSurface(nobj);
```

**SEE ALSO**

`gluBeginCurve`, `gluBeginTrim`, `gluNewNurbsRenderer`, `gluNurbsCurve`, `gluNurbsSurface`, `gluPwlCurve`

---

**gluBeginTrim**

**NAME**

`gluBeginTrim`, `gluEndTrim` — delimit a NURBS trimming loop definition

**C SPECIFICATION**

```c
    void gluBeginTrim(GLUnurbsObj *nobj)    void gluEndTrim(GLUnurbsObj *nobj)
```

**PARAMETERS**

- `nobj` Specifies the NURBS object (created with `gluNewNurbsRenderer`).

**DESCRIPTION**

Use `gluBeginTrim` to mark the beginning of a trimming loop, and `gluEndTrim` to mark the end of a trimming loop. A trimming loop is a set of oriented curve segments (forming a closed curve) that define boundaries of a NURBS surface. You include these trimming loops in the definition of a NURBS surface, between calls to `gluBeginSurface` and `gluEndSurface`.

The definition for a NURBS surface can contain many trimming loops. For example, if you wrote a definition for a NURBS surface that resembled a rectangle with a hole punched out, the definition would contain two trimming loops. One loop would define the outer edge of the rectangle; the other would define the hole punched out of the rectangle. The definitions of each of these trimming loops would be bracketed by `gluBeginTrim`/`gluEndTrim` pairs.

The definition of a single closed trimming loop can consist of multiple curve segments, each described as a piecewise linear curve (see `gluPwlCurve`) or as a single NURBS curve (see `gluNurbsCurve`), or as a combination of both in any order. The only library calls that can appear in a trimming loop definition (between the calls to `gluBeginTrim` and `gluEndTrim`) are `gluPwlCurve` and `gluNurbsCurve`.

The area of the NURBS surface that is displayed is the region in the domain to the left of the trimming curve as the curve parameter increases. Thus, the retained region of the NURBS surface is inside a counterclockwise trimming loop, while the trimming loop for the punched-out hole runs clockwise.

If you use more than one curve to define a single trimming loop, the curve segments must form a closed loop (that is, the endpoint of each curve must be the starting point of the next curve, and the endpoint of the final curve must be the starting point of the first curve). If the endpoints of the curve are not sufficiently close together but not exactly coincident, they will be coerced to match. If the endpoints are not sufficiently close, an error results (see "gluNurbsCallback").

If a trimming loop definition contains multiple curves, the direction of the curves must be consistent (that is, the inside must be to the left of all of the curves). Nested trimming loops are legal as long as the curve orientations alternate correctly. Trimming curves cannot be self-intersecting, nor can they intersect one another (or an error results).

If no trimming information is given for a NURBS surface, the entire surface is drawn.

**EXAMPLE**

This code fragment defines a trimming loop that consists of one piecewise linear curve, and two NURBS curves:

```c
    gluBeginTrim(nobj);    gluPwlCurve(..., GLU_MAP1_TRIM_2);    gluNurbsCurve(..., GLU_MAP1_TRIM_2);    gluNurbsCurve(..., GLU_MAP1_TRIM_3);    gluEndTrim(nobj);
```

**SEE ALSO**

"gluBeginSurface", "gluNewNurbsRenderer", "gluNurbsCallback", "gluNurbsCurve", "gluPwlCurve"

---

**gluBuild1DMipmaps**

**NAME**

`gluBuild1DMipmaps` — create 1-D mipmaps

**C SPECIFICATION**

```c
    int gluBuild1DMipmaps(GLenum target, GLint components, GLint width, GLenum format, GLenum type, void *data)
```

**PARAMETERS**

- `target` Specifies the target texture. Must be `GL_TEXTURE_1D`.
- `components` Specifies the number of color components in the texture. Must be 1, 2, 3, or 4.
- `width` Specifies the width of the texture image.
- `format` Specifies the format of the pixel data. Must be one of `GL_COLOR_INDEX`, `GL_RED`, `GL_GREEN`, `GL_BLUE`, `GL_ALPHA`, `GL_RGBA`, `GL_LUMINANCE`, and `GL_LUMINANCE_ALPHA`.
- `type` Specifies the data type for the texture. Must be one of `GL_UNSIGNED_BYTE`, `GL_BYTE`, `GL_BITMAP`, `GL_UNSIGNED_SHORT`, `GL_SHORT`, `GL_UNSIGNED_INT`, `GL_INT`, or `GL_FLOAT`.
- `data` Specifies a pointer to the image data in memory.

**DESCRIPTION**

`gluBuild1DMipmaps` obtains the input image and generates all mipmap images (using compression if necessary) to the texture object that was specified by the `target` parameter. This function is valid only if the `target` parameter is `GL_TEXTURE_1D`. The `components` parameter determines the number of color components used by the texture. The `width` parameter specifies the width of the texture image. The `format` parameter specifies the format of the pixel data, and `type` specifies the data type for the texture. The `data` parameter is a pointer to the image data in memory.
gluScaleImage) so that the input image can be used as a mipmapmed texture image. glTexImage2D is then called to load each of the images. If the width of the input image is not a power of two, then the image is scaled to the nearest power of two before the mipmaps are generated.

A return value of zero indicates success. Otherwise, a GLU error code is returned (see “gluErrorString”).

Please refer to the glTexImage1D reference page for a description of the acceptable values for the format parameter. See the “glDrawPixels” reference page for a description of the acceptable values for the type parameter.

SEE ALSO
‘glTexImage1D’, ‘gluBuild2DMipmaps’, ‘gluErrorString’, ’gluScaleImage’

**gluBuild2DMipmaps**

**NAME**

gluBuild2DMipmaps – create 2-D mipmaps

**C SPECIFICATION**

```c
int gluBuild2DMipmaps( GLenum target, GLint components, GLint width, GLint height, GLenum format, GLint enumType, void *data )
```

**PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>target</td>
<td>Specifies the target texture. Must be GL_TEXTURE_2D.</td>
</tr>
<tr>
<td>components</td>
<td>Specifies the number of color components in the texture. Must be 1, 2, 3, or 4.</td>
</tr>
<tr>
<td>width</td>
<td>Specifies the width and height, respectively, of the texture image.</td>
</tr>
<tr>
<td>height</td>
<td>Specifies the width and height, respectively, of the texture image.</td>
</tr>
<tr>
<td>format</td>
<td>Specifies the format of the pixel data. Must be one of: GL_COLOR_INDEX, GL_RED, GL_GREEN, GL_BLUE, GL_ALPHA, GL_RGB, GL_RGBA, GL_LUMINANCE, and GL_LUMINANCE_ALPHA.</td>
</tr>
<tr>
<td>type</td>
<td>Specifies the data type for data. Must be one of: GL_UNSIGNED_BYTE, GL_BYTE, GL_BITMAP, GL_UNSIGNED_SHORT, GL_SHORT, GL_UNSIGNED_INT, GL_INT, or GL_FLOAT.</td>
</tr>
<tr>
<td>data</td>
<td>Specifies a pointer to the image data in memory.</td>
</tr>
</tbody>
</table>

**DESCRIPTION**

gluBuild2DMipmaps obtains the input image and generates all mipmap images (using gluScaleImage) so that the input image can be used as a mipmapmed texture image. glTexImage2D is then called to load each of the images. If the dimensions of the input image are not powers of two, then the image is scaled so that both the width and height are powers of two before the mipmaps are generated.

A return value of 0 indicates success. Otherwise, a GLU error code is returned (see “gluErrorString”).

Please refer to the glTexImage1D reference page for a description of the acceptable values for the format parameter. See the “glDrawPixels” reference page for a description of the acceptable values for the type parameter.

SEE ALSO
‘glTexImage1D’, ‘gluBuild2DMipmaps’, ‘gluErrorString’, ”gluScaleImage”

**gluCylinder**

**NAME**

gluCylinder – draw a cylinder

**C SPECIFICATION**

```c
void gluCylinder( GLquadricObj *qobj, GLdouble baseRadius, GLdouble topRadius, GLdouble height, GLint slices, GLint stacks )
```

**PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>qobj</td>
<td>Specifies the quadrics object (created with gluNewQuadric).</td>
</tr>
<tr>
<td>baseRadius</td>
<td>Specifies the radius of the cylinder at z = 0.</td>
</tr>
<tr>
<td>topRadius</td>
<td>Specifies the radius of the cylinder at z = height.</td>
</tr>
<tr>
<td>height</td>
<td>Specifies the height of the cylinder.</td>
</tr>
<tr>
<td>slices</td>
<td>Specifies the number of subdivisions around the z axis.</td>
</tr>
<tr>
<td>stacks</td>
<td>Specifies the number of subdivisions along the z axis.</td>
</tr>
</tbody>
</table>

**DESCRIPTION**

gluCylinder draws a cylinder oriented along the z axis. The base of the cylinder is placed at z = 0, and the top at z = height. Like a sphere, a cylinder is subdivided around the z axis into slices, and along the z axis into stacks.

Note that if topRadius is set to zero, then this routine will generate a cone.

If the orientation is set to GLU_OUTSIDE (with gluQuadricOrientation), then any generated normals point away from the z axis. Otherwise, they point toward the z axis.

If texturing is turned on (with gluQuadricTexture), then texture coordinates are generated so that t ranges linearly from 0.0 at z = 0 to 1.0 at z = height, and s ranges from 0.0 at the +z axis, to 0.25 at the -x axis, to 0.25 at the -y axis, to 0.75 at the +x axis, and back to 1.0 at the +y axis.

**SEE ALSO**

**gluDeleteNurbsRenderer**

**NAME**

gluDeleteNurbsRenderer – destroy a NURBS object

**C SPECIFICATION**

```c
void gluDeleteNurbsRenderer( GLUnurbsObj *nobj )
```

**PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>nobj</td>
<td>Specifies the NURBS object to be destroyed (created with gluNewNurbsRenderer).</td>
</tr>
</tbody>
</table>

**SEE ALSO**
'gluDeleteNurbsRenderer', 'gluNewNurbsRenderer'
gluDeleteNurbsRenderer destroys the NURBS object and frees any memory used by it. Once gluDeleteNurbsRenderer has been called, nobj cannot be used again.

SEE ALSO
"gluNewNurbsRenderer"

NAME

gluDeleteQuadric − destroy a quadrics object

C SPECIFICATION

void gluDeleteQuadric( GLUquadricObj *state )

PARAMETERS

state Specifies the quadrics object to be destroyed (created with gluNewQuadric).

DESCRIPTION

gluDeleteQuadric destroys the quadrics object and frees any memory used by it. Once gluDeleteQuadric has been called, state cannot be used again.

SEE ALSO

"gluNewQuadric"

NAME

gluDeleteTess − destroy a tessellation object

C SPECIFICATION

void gluDeleteTess( GLUtriangulatorObj *tobj )

PARAMETERS

tobj Specifies the tessellation object to destroy (created with gluNewTess).

DESCRIPTION

gluDeleteTess destroys the indicated tessellation object and frees any memory that it used.

SEE ALSO

"gluBeginPolygon", "gluNewTess", "gluTessCallback"

NAME

gluDisk − draw a disk

C SPECIFICATION

void gluDisk( GLUquadricObj *qobj, GLdouble innerRadius, GLdouble outerRadius, GLint slices, GLint loops )

PARAMETERS

qobj Specifies the quadrics object (created with gluNewQuadric).
innerRadius Specifies the inner radius of the disk (may be 0).
outerRadius Specifies the outer radius of the disk.
slices Specifies the number of subdivisions around the z axis.
loops Specifies the number of concentric rings about the origin into which the disk is subdivided.

DESCRIPTION

gluDisk renders a disk on the z = 0 plane. The disk has a radius of outerRadius, and contains a concentric circular hole with a radius of innerRadius. If innerRadius is 0, then no hole is generated. The disk is subdivided around the z axis into slices (like pizza slices), and also about the z axis into rings (as specified by slices and loops, respectively).

With respect to orientation, the +z side of the disk is considered to be "outside" (see gluQuadricOrientation ). This means that if the orientation is set to GLU_OUTSIDE, then any normals generated point along the +z axis. Otherwise, they point along the −z axis. If texturing is turned on (with gluQuadricTexture ), texture coordinates are generated linearly such that where r = outerRadius , the value at (0, r, 0) is (1, 0.5), at (r, 0, 0) it is (0.5, 1), at (−r, 0, 0) it is (0, 0.5), and at (0, −r, 0) it is (0.5, 0).

SEE ALSO

"gluCylinder", "gluNewQuadric", "gluPartialDisk", "gluQuadricOrientation", "gluQuadricTexture", "gluSphere"

NAME

gluErrorString − produce an error string from an OpenGL or GLU error code

C SPECIFICATION

const GLubyte* gluErrorString( GLenum errorCode )

PARAMETERS

erErrorCode Specifies an OpenGL or GLU error code.
**DESCRIPTION**

`gluErrorString` produces an error string from an OpenGL or GLU error code. The string is in an ISO Latin 1 format. For example, `gluErrorString(GL_OUT_OF_MEMORY)` returns the string out of memory.

The standard GLU error codes are `GLU_INVALID_ENUM`, `GLU_INVALID_VALUE`, and `GLU_OUT_OF_MEMORY`. Certain other GLU functions can return specialized error codes through callbacks. Refer to the `glGetError` reference page for the list of OpenGL error codes.

**SEE ALSO**

`glGetError`, `gluNurbsCallback`, `gluQuadricCallback`, `gluTessCallback`

**NAME**

`gluErrorString` — produces an error string

---

**DESCRIPTION**

`gluGetNurbsProperty` is used to retrieve properties stored in a NURBS object. These properties affect the way that NURBS curves and surfaces are rendered. Please refer to the `gluNurbsProperty` reference page for information about what the properties are and what they do.

**SEE ALSO**

`gluGetNurbsProperty`, `gluNurbsRenderer`, `gluNurbsProperty`

**NAME**

`gluGetNurbsProperty` — get a NURBS property

---

**DESCRIPTION**

`gluLoadSamplingMatrices` uses `modelMatrix`, `projMatrix`, and `viewport` to recompute the sampling and culling matrices stored in `nobj`. The sampling matrix determines how finely a NURBS curve or surface must be tessellated to satisfy the sampling tolerance (as determined by the `GLU_SAMPLING_TOLERANCE` property). The culling matrix is used in deciding if a NURBS curve or surface should be culled before rendering (when the `GLU_CULLING` property is turned on).

`gluLoadSamplingMatrices` is necessary only if the `GLU_AUTO_LOAD_MATRIX` property is turned off (see `gluNurbsProperty`). Although it can be convenient to leave the `GLU_AUTO_LOAD_MATRIX` property turned on, there can be a performance penalty for doing so.

(A round trip to the OpenGL server is needed to fetch the current values of the modelview matrix, projection matrix, and viewport.)

**SEE ALSO**

`gluGetNurbsProperty`, `gluNurbsRenderer`, `gluNurbsProperty`

**NAME**

`gluLoadSamplingMatrices` — load NURBS sampling and culling matrices

---

**DESCRIPTION**

`gluLookAt` creates a viewing matrix derived from an eye point, a reference point indicating the center of the scene, and an up vector. The matrix maps the reference point to the origin, so that, when a typical projection matrix is used, the center of the scene maps to the center of the viewport. Similarly, the direction described by the up vector projected onto the viewing plane is mapped to the positive y axis so that it points upward in the viewport. The up vector must not be parallel to the line of sight from the eye to the reference point.

The matrix generated by `gluLookAt` postmultiplies the current matrix.

**NAME**

`gluLookAt` — define a viewing transformation

---

**PARAMETERS**

- `nobj` Specifies the NURBS object (created with `gluNewNurbsRenderer`).
- `modelMatrix` Specifies a modelview matrix (as from a `glGetFloatv` call).
- `projMatrix` Specifies a projection matrix (as from a `glGetFloatv` call).
- `viewport` Specifies a viewport (as from a `glGetIntegerv` call).

**C SPECIFICATION**

```c
void gluLoadSamplingMatrices( GLUnurbsObj *nobj, const GLfloat modelMatrix[16], const GLfloat projMatrix[16], const GLint viewport[4] );
```
**gluNewNurbsRenderer**

**NAME**

`gluNewNurbsRenderer` – create a NURBS object

**C SPECIFICATION**

GLUnurbsObj* `gluNewNurbsRenderer` (void)

**DESCRIPTION**

`gluNewNurbsRenderer` creates and returns a pointer to a new NURBS object. This object must be referred to when calling NURBS rendering and control functions. A return value of zero means that there is not enough memory to allocate the object.

**SEE ALSO**

`gluBeginCurve`, `gluBeginSurface`, `gluBeginTrim`, `gluDeleteNurbsRenderer`, `gluNurbsCallback`, `gluNurbsProperty`

**gluNewQuadric**

**NAME**

`gluNewQuadric` – create a quadrics object

**C SPECIFICATION**

GLUquadricObj* `gluNewQuadric` (void)

**DESCRIPTION**

`gluNewQuadric` creates and returns a pointer to a new quadrics object. This object must be referred to when calling quadrics rendering and control functions. A return value of zero means that there is not enough memory to allocate the object.

**SEE ALSO**

`gluCylinder`, `gluDeleteQuadric`, `gluDisk`, `gluPartialDisk`, `gluQuadricCallback`, `gluQuadricDrawStyle`, `gluQuadricNormals`, `gluQuadricOrientation`, `gluQuadricTexture`, `gluSphere`

**gluNewTess**

**NAME**

`gluNewTess` – create a tessellation object

**C SPECIFICATION**

GLUtriangulatorObj* `gluNewTess` (void)

**DESCRIPTION**

`gluNewTess` creates and returns a pointer to a new tessellation object. This object must be referred to when calling tessellation functions. A return value of zero means that there is not enough memory to allocate the object.

**SEE ALSO**

`gluBeginPolygon`, `gluDeleteTess`, `gluTessCallback`

**gluNextContour**

**NAME**

`gluNextContour` – mark the beginning of another contour

**C SPECIFICATION**

void `gluNextContour` (GLUtriangulatorObj *tobj, GLenum type)

**PARAMETERS**

tobj

Specifies the tessellation object (created with `gluNewTess`).

type

Specifies the type of the contour being defined. Valid values are `GLU_EXTERIOR`, `GLU_INTERIOR`, `GLU_UNKNOWN`, `GLU_CCW`, and `GLU_CW`.

**DESCRIPTION**

`gluNextContour` is used in describing polygons with multiple contours. After the first contour has been described through a series of `gluTessVertex` calls, a `gluNextContour` call indicates that the previous contour is complete and that the next contour is about to begin. Another series of `gluTessVertex` calls is then used to describe the new contour. This process can be repeated until all contours have been described.

type defines what type of contour follows. The legal contour types are as follows:

- **GLU_EXTERIOR**
  An exterior contour defines an exterior boundary of the polygon.

- **GLU_INTERIOR**
  An interior contour defines an interior boundary of the polygon (such as a hole).

- **GLU_UNKNOWN**
  An unknown contour is analyzed by the library to determine if it is interior or exterior.

- **GLU_CCW**
  The first `GLU_CCW` or `GLU_CW` contour is considered to be exterior. All other contours are considered to be exterior if they are oriented in the same direction (clockwise or counterclockwise) as the first contour, and interior if they are not. If one contour is of type `GLU_CCW` or `GLU_CW` and all contours must be of the same type (if they are not, then all `GLU_CCW` and `GLU_CW` contours will be changed to `GLU_UNKNOWN`). Note that there is no real difference between the `GLU_CCW` and `GLU_CW` contour types.
gluNextContour can be called before the first contour is described to define the type of the first contour. If gluNextContour is not called before the first contour, then the first contour is marked GLU_EXTERIOR.

EXAMPLE
A quadrilateral with a triangular hole in it can be described as follows:

```c
    glBeginPolygon(tobj);
    gluTessVertex(tobj, v1, v1);
    gluTessVertex(tobj, v2, v2);
    gluTessVertex(tobj, v3, v3);
    gluTessVertex(tobj, v4, v4);
    gluNextContour(tobj, GLU_INTERIOR);
    gluTessVertex(tobj, v5, v5);
    gluTessVertex(tobj, v6, v6);
    gluTessVertex(tobj, v7, v7);
    glEndPolygon(tobj);
```

SEE ALSO
"gluBeginPolygon", "gluNewTess", "gluTessCallback", "gluTessVertex"

 gluNurbsCurve

NAME
    gluNurbsCurve — define the shape of a NURBS curve

C SPECIFICATION
void gluNurbsCurve( GLUnurbsObj *nobj, GLint nknots, GLfloat *knot, GLint stride, GLfloat *ctlarray, GLint order, GLenum type )

PARAMETERS
nobj Specifies the NURBS object (created with gluNewNurbsRenderer).

nknots Specifies the number of knots in knot.  nknots equals the number of control points plus the order.

knot Specifies an array of nknots nondecreasing knot values.

stride Specifies the offset (as a number of single-precision floating-point values) between successive curve control points.

darray Specifies a pointer to an array of control points.  The coordinates must agree with type, specified below.

order Specifies the order of the NURBS curve.  order equals degree + 1, hence a cubic curve has an order of 4.

type Specifies the type of the curve.  If this curve is defined within a gluBeginCurve/ gluEndCurve pair, then the type can be any of the valid one-dimensional evaluator types (such as GL_MAP1_VERTEX_3 or GL_MAP1_COLOR_4).  Between a gluBeginTrim/gluEndTrim pair, the only valid types are GLU_MAP1_TRIM_2 and GLU_MAP1_TRIM_3.

DESCRIPTION
Use gluNurbsCurve to describe a NURBS curve.  When gluNurbsCurve appears between a gluBeginCurve/gluEndCurve pair, it is used to describe a curve to be rendered.  Positional, texture, and color coordinates are associated by presenting each as a separate gluNurbsCurve between a gluBeginCurve/gluEndCurve pair.  No more than one call to gluNurbsCurve for each of color, position, and texture data can be made within a single gluBeginCurve/gluEndCurve pair.  Exactly one call must be made to describe the position of the curve (a type of GL_MAP1_VERTEX_3 or GL_MAP1_COLOR_4).  Between a gluBeginTrim/gluEndTrim pair, the only valid types are GLU_MAP1_TRIM_2 and GLU_MAP1_TRIM_3.

EXAMPLE
The following commands render a textured NURBS curve with normals:

```c
    gluBeginCurve(nobj);
    gluNurbsCurve(nobj, ..., GL_MAP1_TEXTURE_COORD_2);
    gluNurbsCurve(nobj, ..., GL_MAP1_NORMAL);
    gluEndCurve(nobj);
```

SEE ALSO
"gluBeginCurve", "gluNewNurbsRenderer", "gluBeginTrim", "gluEndTrim"
The gluNurbsProperty function is used to control properties stored in a NURBS object. These properties affect the way that a NURBS curve is rendered. The legal values for property are as follows:

**GLU_SAMPLING_TOLERANCE**
- Specifies the maximum length, in pixels, of line segments or edges of polygons used to render NURBS curves or surfaces. The NURBS code is conservative when rendering a curve or surface, so the actual length can be somewhat shorter. The default value is 50.0 pixels.

**GLU_DISPLAY_MODE**
- Specifies how a NURBS surface should be rendered. The values can be set to GLU_FILL, GLU_OUTLINE_POLYGON, or GLU_OUTLINE_PATCH. When set to GLU_FILL, the surface is rendered as a set of polygons. GLU_OUTLINE_POLYGON instructs the NURBS library to draw only the outlines of the polygons created by tessellation. GLU_OUTLINE_PATCH causes just the outlines of patches and trim curves defined by the user to be drawn. The default value is GLU_FILL.

**GLU_CULLING**
- Specifies a Boolean value that, when set to GL_TRUE, indicates that a NURBS curve should be discarded prior to tessellation if its control points lie outside the current viewport. The default is GL_FALSE (because a NURBS curve cannot fail entirely within the convex hull of its control points).

**GLU_AUTO_LOAD_MATRIX**
- Specifies a Boolean value. When set to GL_TRUE, the NURBS code downloads the projection matrix, the modelview matrix, and the viewport from the OpenGL server to compute sampling and culling matrices for each NURBS curve that is rendered. Sampling and culling matrices are required to determine the tessellation of a NURBS surface into line segments or polygons and to cull a NURBS surface if it lies outside of the viewport. If this mode is set to GL_FALSE, then the user needs to provide a projection matrix, a modelview matrix, and a viewport for the NURBS render to use to construct sampling and culling matrices. This can be done with the gluLoadSamplingMatrices function. The default for this mode is GL_TRUE.

Changing this mode from GL_TRUE to GL_FALSE does not affect the sampling and culling matrices until gluLoadSamplingMatrices is called.

**SEE ALSO**
- `gluBeginCurve`, `gluBeginTrim`, `gluNewNurbsRenderer`, `gluPwlCurve`

### gluNurbsProperty

**NAME**
- gluNurbsProperty — set a NURBS property

**C SPECIFICATION**

```c
void gluNurbsProperty(GLUnurbsObj *nobj, GLenum property, GLfloat value);
```

**PARAMETERS**
- `nobj` Specifies the NURBS object (created with gluNewNurbsRenderer).
- `property` Specifies the property to be set. Valid values are GLU_SAMPLING_TOLERANCE, GLU_DISPLAY_MODE, GLU_CULLING, and GLU_AUTO_LOAD_MATRIX.
- `value` Specifies the value to which to set the indicated property.

**DESCRIPTION**
- gluNurbsProperty is used to control properties stored in a NURBS object. These properties affect the way that a NURBS curve is rendered. The legal values for property are as follows:

**GLU_SAMPLING_TOLERANCE**
- Specifies the maximum length, in pixels, of line segments or edges of polygons used to render NURBS curves or surfaces. The NURBS code is conservative when rendering a curve or surface, so the actual length can be somewhat shorter. The default value is 50.0 pixels.

**GLU_DISPLAY_MODE**
- Specifies how a NURBS surface should be rendered. The values can be set to GLU_FILL, GLU_OUTLINE_POLYGON, or GLU_OUTLINE_PATCH. When set to GLU_FILL, the surface is rendered as a set of polygons. GLU_OUTLINE_POLYGON instructs the NURBS library to draw only the outlines of the polygons created by tessellation. GLU_OUTLINE_PATCH causes just the outlines of patches and trim curves defined by the user to be drawn. The default value is GLU_FILL.

**GLU_CULLING**
- Specifies a Boolean value that, when set to GL_TRUE, indicates that a NURBS curve should be discarded prior to tessellation if its control points lie outside the current viewport. The default is GL_FALSE (because a NURBS curve cannot fail entirely within the convex hull of its control points).

**GLU_AUTO_LOAD_MATRIX**
- Specifies a Boolean value. When set to GL_TRUE, the NURBS code downloads the projection matrix, the modelview matrix, and the viewport from the OpenGL server to compute sampling and culling matrices for each NURBS curve that is rendered. Sampling and culling matrices are required to determine the tessellation of a NURBS surface into line segments or polygons and to cull a NURBS surface if it lies outside of the viewport. If this mode is set to GL_FALSE, then the user needs to provide a projection matrix, a modelview matrix, and a viewport for the NURBS render to use to construct sampling and culling matrices. This can be done with the gluLoadSamplingMatrices function. The default for this mode is GL_TRUE.

Changing this mode from GL_TRUE to GL_FALSE does not affect the sampling and culling matrices until gluLoadSamplingMatrices is called.

**SEE ALSO**
- `gluBeginCurve`, `gluBeginTrim`, `gluNewNurbsRenderer`, `gluPwlCurve`
surface (a type of GL_MAP2_VERTEX_3 or GL_MAP2_VERTEX_4).

A NURBS surface can be trimmed by using the commands
*gluNurbsCurve* and *gluPwlCurve* between calls to *
*gluBeginTrim* and *gluEndTrim*.

Note that a *
*gluNurbsSurface* with *sknot_count* knots in the u direction and
*tknot_count* knots in the v direction with orders *
*sorder* and *
torder* must have (*sknot_count* − *sorder*) × (*tknot_count* −
torder) control points.

**EXAMPLE**

The following commands render a textured NURBS surface with normals; the texture coordinates andnormals are also NURBS surfaces:

```c
    gluBeginSurface(nobj);
    gluNurbsSurface(nobj, ..., GL_MAP2_TEXTURE_COORD_2);
    gluNurbsSurface(nobj, ..., GL_MAP2_NORMAL);
    gluNurbsSurface(nobj, ..., GL_MAP2_VERTEX_4);
    gluEndSurface(nobj);
```

**SEE ALSO**

"gluBeginSurface", "gluBeginTrim", "gluNewNurbsRenderer", "gluNurbsCurve", "gluPwlCurve"

---

**gluOrtho2D**

**NAME**

*gluOrtho2D* — define a 2-D orthographic projection matrix

**C SPECIFICATION**

```c
    void gluOrtho2D(GLdouble left, GLdouble right,
                    GLdouble bottom, GLdouble top)
```

**PARAMETERS**

- **left**
  Specify the coordinates for the left and right vertical clipping planes.
- **right**
  Specify the coordinates for the left and right vertical clipping planes.
- **bottom**
  Specify the coordinates for the bottom and top horizontal clipping planes.
- **top**
  Specify the coordinates for the bottom and top horizontal clipping planes.

**DESCRIPTION**

*gluOrtho2D* sets up a two-dimensional orthographic viewing region. This is equivalent to calling *
*glOrtho* with near = −1 and far = 1.

**SEE ALSO**

"gluPerspective", "gluPartialDisk"

---

**gluPartialDisk**

**NAME**

*gluPartialDisk* — draw an arc of a disk

**C SPECIFICATION**

```c
    void gluPartialDisk(GLUquadricObj *qobj,
                        GLdouble innerRadius, GLdouble outerRadius,
                        GLint slices, GLint loops, GLdouble startAngle,
                        GLdouble sweepAngle)
```

**PARAMETERS**

- **qobj**
  Specifies a quadrics object (created with *
  *gluNewQuadric*).
- **innerRadius**
  Specifies the inner radius of the partial disk (can be zero).
- **outerRadius**
  Specifies the outer radius of the partial disk.
- **slices**
  Specifies the number of subdivisions around the z axis.
- **loops**
  Specifies the number of concentric rings about the origin into which the partial disk is subdivided.
- **startAngle**
  Specifies the starting angle, in degrees, of the disk portion.
- **sweepAngle**
  Specifies the sweep angle, in degrees, of the disk portion.

**DESCRIPTION**

*gluPartialDisk* renders a partial disk on the z = 0 plane. A partial disk is similar to a full disk,
except that only the subset of the disk from startAngle through startAngle + sweepAngle is included
(where 0 degrees is along the +y axis, 90 degrees along the +x axis, 180 along the −y axis, and 270 along
the −x axis).

The partial disk has a radius of outerRadius, and contains a concentric circular hole with a radius of
innerRadius. If innerRadius is zero, then no hole is generated. The partial disk is subdivided around
the z axis into slices (like pizza slices), and also about the z axis into rings (as specified by slices and
loops, respectively).

With respect to orientation, the +z side of the partial disk is considered to be outside (see *
*gluQuadricOrientation*). This means that if the orientation is set to *
*GLU_OUTSIDE*, then any normals generated point along the +z axis. Otherwise, they point along the −z axis.

If texturing is turned on (with *
*gluQuadricTexture*), texture coordinates are generated linearly such that
where r = outerRadius, the value at (r, 0, 0) is (1, 0.5), at (0, r, 0) it is (0.5, 1), at (−r, 0, 0) it is (0, 0.5),
and at (0, −r, 0) it is (0.5, 0).

**SEE ALSO**

"gluCylinder", "gluDisk", "gluNewQuadric", "gluQuadricOrientation", "gluQuadricTexture", "gluSphere"
aspect ratio is the ratio of x (width) to y (height).

DESCRIPTION

**gluPerspective** specifies a viewing frustum into the world coordinate system. In general, the aspect ratio in **gluPerspective** should match the aspect ratio of the associated viewport. For example, aspect = 2.0 means the viewer’s angle of view is twice as wide in x as it is in y. If the viewport is twice as wide as it is tall, it displays the image without distortion.

The matrix generated by **gluPerspective** is multiplied by the current matrix, just as if **glMultMatrix** were called with the generated matrix. To load the perspective matrix onto the current matrix stack instead, precede the call to **gluPerspective** with a call to **glLoadIdentity**.

SEE ALSO

"glFrustum", "glLoadIdentity", "glMultMatrix", "gluOrtho2D"

**gluPickMatrix**

NAME

**gluPickMatrix** — define a picking region

C SPECIFICATION

```c
void gluPickMatrix ( GLdouble x, GLdouble y, GLdouble width, GLdouble height, GLint viewport[4])
```

PARAMETERS

- x, y Specify the center of a picking region in window coordinates.
- width, height Specify the width and height, respectively, of the picking region in window coordinates.
- viewport Specifies the current viewport (as from a **glGetIntegerv** call).

DESCRIPTION

**gluPickMatrix** creates a projection matrix that can be used to restrict drawing to a small region of the viewport. This is typically useful to determine what objects are being drawn near the cursor. Use **gluPickMatrix** to restrict drawing to a small region around the cursor. Then, enter selection mode with **glRenderMode** and render the scene. All primitives that would have been drawn near the cursor are identified and stored in the selection buffer.

The matrix created by **gluPickMatrix** is multiplied by the current matrix just as if **glMultMatrix** is called with the generated matrix. To effectively use the generated pick matrix for picking, first call **glLoadIdentity** to load an identity matrix onto the perspective matrix stack. Then call **gluPickMatrix**, and finally, call a command such as **gluPerspective** to multiply the perspective matrix by the pick matrix.

When using **gluPickMatrix** to pick NURBS, be careful to turn off the NURBS property **GLU_AUTO_LOAD_MATRIX**. If **GLU_AUTO_LOAD_MATRIX** is not turned off, then any NURBS surface rendered is subdivided differently with the pick matrix than the way it was subdivided without the pick matrix.

EXAMPLE

```
When rendering a scene as follows:

```c
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluPerspective(...);
glMatrixMode(GL_MODELVIEW);/* Draw the scene */
```

a portion of the viewport can be selected as a pick region like this:

```c
glMatrixMode(GL_PROJECTION);
glLoadIdentity();
gluPickMatrix(x, y, width, height, viewport);
gluPerspective(...);
glMatrixMode(GL_MODELVIEW);/* Draw the scene */
```

SEE ALSO

"glGet", "glLoadIdentity", "glMultMatrix", "glRenderMode", "gluPerspective"

**gluProject**

NAME

**gluProject** — map object coordinates to window coordinates

C SPECIFICATION

```c
int gluProject ( GLdouble objx, GLdouble objy, GLdouble objz, const GLdouble modelMatrix[16], const GLdouble projMatrix[16], const GLint viewport[4], GLdouble *winx, GLdouble *winy, GLdouble *winz)
```

PARAMETERS

- objx, objy, objz Specify the object coordinates.
- modelMatrix Specifies the current modelview matrix (as from a **glGetDoublev** call).
- projMatrix Specifies the current projection matrix (as from a **glGetDoublev** call).
- viewport Specifies the current viewport (as from a **glGetIntegerv** call).
- winx, winy, winz Return the computed window coordinates.

DESCRIPTION

**gluProject** transforms the specified object coordinates into window coordinates using modelMatrix, projMatrix, and viewport. The result is stored in winx, winy, and winz. A return value of **GL_TRUE** indicates success, and **GL_FALSE** indicates failure.

SEE ALSO

"glGet", "gluUnProject"
NAME
gluPwlCurve — describe a piecewise linear NURBS trimming curve

C SPECIFICATION
void gluPwlCurve( GLUnurbsObj *nobj, GLint count, GLfloat *array, GLint stride, GLenum type )

PARAMETERS
nobj Specifies the NURBS object (created with gluNewNurbsRenderer).
count Specifies the number of points on the curve.
array Specifies an array containing the curve points.
stride Specifies the offset (a number of single-precision floating-point values) between points on the curve.
type Specifies the type of curve. Must be either GLU_MAP1_TRIM_2 or GLU_MAP1_TRIM_3.

DESCRIPTION
gluPwlCurve describes a piecewise linear trimming curve for a NURBS surface. A piecewise linear curve consists of a list of coordinates of points in the parameter space for the NURBS surface to be trimmed. These points are connected with line segments to form a curve. If the curve is an approximation to a real curve, the points should be close enough that the resulting path appears curved at the resolution used in the application.

If type is GLU_MAP1_TRIM_2 then it describes a curve in two-dimensional (u and v) parameter space. If it is GLU_MAP1_TRIM_3 then it describes a curve in two-dimensional homogeneous (u, v, and w) parameter space. Please refer to the gluBeginTrim reference page for more information about trimming curves.

SEE ALSO

gluQuadricCallback

NAME
gluQuadricCallback — define a callback for a quadrics object

C SPECIFICATION
void gluQuadricCallback( GLUquadricObj *quadObject, GLenum which, void (*fn)( ) )

PARAMETERS
quadObject Specifies the quadrics object (created with gluNewQuadric).
which Specifies the callback being defined. The only valid value is GLU_ERROR.
fn Specifies the function to be called.

DESCRIPTION
gluQuadricCallback is used to define a new callback to be used by a quadrics object. If the specified callback is already defined, then it is replaced. If fn is NULL, then any existing callback is erased.

The one legal callback is GLU_ERROR:
GLU_ERROR The function is called when an error is encountered. Its single argument is of type GLenum, and it indicates the specific error that occurred. Character strings describing these errors can be retrieved with the gluErrorString call.

SEE ALSO
‘gluBeginCurve’, ‘gluNewQuadric’

gluQuadricDrawStyle

NAME
gluQuadricDrawStyle — specify the draw style desired for quadrics

C SPECIFICATION
void gluQuadricDrawStyle( GLUquadricObj *quadObject, GLenum drawStyle )

PARAMETERS
quadObject Specifies the quadrics object (created with gluNewQuadric).
drawStyle Specifies the desired draw style. Valid values are GLU_FILL, GLU_LINE, GLU_SILHOUETTE, and GLU_POINT.

DESCRIPTION
gluQuadricDrawStyle specifies the draw style for quadrics rendered with quadObject. The legal values are as follows:
GLU_FILL Quadrics are rendered with polygon primitives. The polygons are drawn in a counterclockwise fashion with respect to their normals (as defined with gluQuadricOrientation).
GLU_LINE Quadrics are rendered as a set of lines.
GLU_SILHOUETTE Quadrics are rendered as a set of lines, except that edges separating coplanar faces will not be drawn.
GLU_POINT Quadrics are rendered as a set of points.

SEE ALSO
‘gluNewQuadric’, ‘gluQuadricNormals’, ‘gluQuadricOrientation’, ‘gluQuadricTexture’

gluQuadricNormals

NAME
gluQuadricNormals — specify what kind of normals are desired for quadrics

C SPECIFICATION
void gluQuadricNormals( GLUquadricObj *quadObject, GLenum which )

PARAMETERS
quadObject Specifies the quadrics object (created with gluNewQuadric).
which Specifies the callback being defined. The only valid value is GLU_ERROR.

DESCRIPTION
gluQuadricNormals is used to define a new callback to be used by a quadrics object. If the specified callback is already defined, then it is replaced. If fn is NULL, then any existing callback is erased.
PARAMETERS
quadObject  Specifies the quadrics object (created with gluNewQuadric).
normals    Specifies the desired type of normals. Valid values are GLU_NONE, GLU_FLAT, and GLU_SMOOTH.

DESCRIPTION
gluQuadricNormals specifies what kind of normals are desired for quadrics rendered with quadObject. The legal values are as follows:
GLU_NONE No normals are generated.
GLU_FLAT One normal is generated for every facet of a quadric.
GLU_SMOOTH One normal is generated for every vertex of a quadric. This is the default.

SEE ALSO
‘gluNewQuadric’, ‘gluQuadricDrawStyle’, ‘gluQuadricOrientation’, ‘gluQuadricTexture’

NAME

NAME

gluQuadricOrientation – specify inside/outside orientation for quadrics

C SPECIFICATION

void gluQuadricOrientation( GLUquadricObj *quadObject, GLenum orientation )

PARAMETERS
quadObject  Specifies the quadrics object (created with gluNewQuadric).
orientation Specifies the desired orientation. Valid values are GLU_OUTSIDE and GLU_INSIDE.

DESCRIPTION
gluQuadricOrientation specifies what kind of orientation is desired for quadrics rendered with quadObject. The orientation values are as follows:
GLU_OUTSIDE Quadrics are drawn with normals pointing outward.
GLU_INSIDE  Normals point inward. The default is GLU_OUTSIDE.
Note that the interpretation of outward and inward depends on the quadric being drawn.

SEE ALSO
‘gluNewQuadric’, ‘gluQuadricDrawStyle’, ‘gluQuadricNormals’, ‘gluQuadricTexture’

NAME

NAME

gluQuadricTexture – specify if texturing is desired for quadrics

C SPECIFICATION

void gluQuadricTexture( GLUquadricObj *quadObject, GLboolean textureCoords )

PARAMETERS
quadObject  Specifies the quadrics object (created with gluNewQuadric).
textureCoords Specifies a flag indicating if texture coordinates should be generated.

DESCRIPTION
gluQuadricTexture specifies if texture coordinates should be generated for quadrics rendered with quadObject. If the value of textureCoords is GL_TRUE, then texture coordinates are generated, and if textureCoords is GL_FALSE, they are not. The default is GL_FALSE.
The manner in which texture coordinates are generated depends upon the specific quadric rendered.

SEE ALSO
‘gluNewQuadric’, ‘gluQuadricDrawStyle’, ‘gluQuadricNormals’, ‘gluQuadricOrientation’

NAME

NAME

gluScaleImage – scale an image to an arbitrary size

C SPECIFICATION

int gluScaleImage( GLenum format, GLint widthin, GLint heightin, GLenum typein, const void *datain, GLint widthout, GLint heightout, GLenum typeout, void *dataout )

PARAMETERS
format  Specifies the format of the pixel data. The following symbolic values are valid:
         GL_COLOR_INDEX, GL_STENCIL_INDEX, GL_DEPTH_COMPONENT, GL_RED, GL_GREEN, GL_BLUE, GL_ALPHA, GL_RGB, GL_RGBA, GL_LUMINANCE, and GL_LUMINANCE_ALPHA.
widthin, heightin Specify the width and height, respectively, of the source image that is scaled.
typein  Specifies the data type for datain. Must be one of GL_UNSIGNED_BYTE, GL_BYTE, GL_BITMAP, GL_UNSIGNED_SHORT, GL_SHORT, GL_UNSIGNED_INT, GL_INT, or GL_FLOAT.
datain  Specifies a pointer to the source image.
widthout, heightout Specify the width and height, respectively, of the destination image.
typeout Specifies the data type for dataout. Must be one of GL_UNSIGNED_BYTE, GL_BYTE, GL_BITMAP, GL_UNSIGNED_SHORT, GL_SHORT, GL_UNSIGNED_INT, GL_INT, or GL_FLOAT.
dataout Specifies a pointer to the destination image.

DESCRIPTION
gluScaleImage scales a pixel image using the appropriate pixel store modes to unpack data from the source image and pack data into the destination image.
When shrinking an image, `gluScaleImage` uses a box filter to sample the source image and create pixels for the destination image. When magnifying an image, the pixels from the source image are linearly interpolated to create the destination image.

A return value of zero indicates success, otherwise a GLU error code is returned indicating what the problem was (see "gluErrorString").

Please refer to the `glReadPixels` reference page for a description of the acceptable values for the format, typein, and typeout parameters.

**SEE ALSO**
- `gluDrawPixels`, `gluReadPixels`, `gluBuild1DMipmaps`, `gluBuild2DMipmaps`, `gluErrorString`

---

### gluTessCallback

- define a callback for a tessellation object

**C SPECIFICATION**

```c
void gluTessCallback(GLUtriangleObject *tobj, GLenum which, void (*fn)());
```

**PARAMETERS**

- `tobj` Specifies the tessellation object (created with `gluNewTess`).
- `which` Specifies the callback being defined. The following values are valid: `GLU_BEGIN`, `GLU_EDGE_FLAG`, `GLU_VERTEX`, `GLU_END`, and `GLU_ERROR`.
- `fn` Specifies the function to be called.

**DESCRIPTION**

`gluTessCallback` is used to indicate a callback to be used by a tessellation object. If the specified callback is already defined, then it is replaced. If `fn` is `NULL`, then the existing callback is erased.

These callbacks are used by the tessellation object to describe how a polygon specified by the user is broken into triangles. The legal callbacks are as follows:

- **GLU_BEGIN**: The begin callback is invoked like `glBegin` to indicate the start of a (triangle) primitive. The function takes a single argument of type `GLenum` that is either `GL_TRIANGLE_STRIP` or `GL_TRIANGLES`.

  **PARAMETERS**
  - `obj` Specifies the polygon object.
  - `which` Specifies the callback being defined. The following values are valid: `GLU_BEGIN`, `GLU_EDGE_FLAG`, `GLU_VERTEX`, `GLU_END`, and `GLU_ERROR`.
  - `fn` Specifies the function to be called.

- **GLU_EDGE_FLAG**: The edge flag callback is similar to `glEdgeFlag`. The function takes a single `GLboolean` flag that indicates which edges of the created triangles were part of the original polygon defined by the user, and which were created by the tessellation process. If the flag is `GL_TRUE`, then each vertex that follows begins an edge that was part of the original polygon. If the flag is `GL_FALSE`, then each vertex that follows begins an edge that was generated by the tessellator. The edge flag callback (if defined) is invoked before the first vertex callback is made. Since triangle fans and triangle strips do not support edge flags, the begin callback is not called with `GL_TRIANGLE_STRIP` if an edge flag callback is provided. Instead, the fans and strips are converted to independent triangles.

  **PARAMETERS**
  - `obj` Specifies the polygon object.
  - `which` Specifies the callback being defined. The following values are valid: `GLU_BEGIN`, `GLU_EDGE_FLAG`, `GLU_VERTEX`, `GLU_END`, and `GLU_ERROR`.
  - `fn` Specifies the function to be called.

- **GLU_VERTEX**: The vertex callback is invoked between the begin and end callbacks. It is similar to `gluErrorString` and it defines the vertices of the triangles created by the tessellation process. The function takes a pointer as its only argument. This pointer is identical to the opaque pointer provided by the user when the vertex was described (see "gluTessVertex").

  **PARAMETERS**
  - `tobj` Specifies the tessellation object (created with `gluNewTess`).
  - `which` Specifies the callback being defined. The following values are valid: `GLU_BEGIN`, `GLU_EDGE_FLAG`, `GLU_VERTEX`, `GLU_END`, and `GLU_ERROR`.
  - `fn` Specifies the function to be called.

- **GLU_END**: The end callback serves the same purpose as `gluErrorString`. It indicates the end of a primitive and it takes no arguments.

  **PARAMETERS**
  - `tobj` Specifies the tessellation object (created with `gluNewTess`).
  - `which` Specifies the callback being defined. The following values are valid: `GLU_BEGIN`, `GLU_EDGE_FLAG`, `GLU_VERTEX`, `GLU_END`, and `GLU_ERROR`.
  - `fn` Specifies the function to be called.

- **GLU_ERROR**: The error callback is called when an error is encountered. The one argument is of type `GLenum`, and it indicates the specific error that occurred. There are eight errors unique to polygon tessellation, named `GLU_TESS_ERROR1` through `GLU_TESS_ERROR8`. Character strings describing these errors can be retrieved with the `gluErrorString` call.

  **PARAMETERS**
  - `tobj` Specifies the tessellation object (created with `gluNewTess`).
  - `which` Specifies the callback being defined. The following values are valid: `GLU_BEGIN`, `GLU_EDGE_FLAG`, `GLU_VERTEX`, `GLU_END`, and `GLU_ERROR`.
  - `fn` Specifies the function to be called.

**EXAMPLE**

Polygons tessellated can be rendered directly like this:

```c
gluTessCallback(tobj, GLU_BEGIN, glBegin);
gluTessCallback(tobj, GLU_VERTEX, glVertex3dv);
```
gluTessCallback(tobj, GLU_VERTEX, glVertex3dv);
gluTessCallback(tobj, GLU_END, glEnd);
gluBeginPolygon(tobj);   
gluTessVertex(tobj, v, v);   
...   
gluEndPolygon(tobj);

Typically, the tessellated polygon should be stored in a display list so that it does not need to be
retessellated every time it is rendered.

SEE ALSO
"glBegin", "glEdgeFlag", "glVertex", "gluErrorString", "gluNewTess", "gluTessVertex"

gluTessVertex

NAME

gluTessVertex – specify a vertex on a polygon

C SPECIFICATION

void gluTessVertex ( GLUtriangulatorObj *tobj, GLdouble v[3], void *data )

PARAMETERS

- *tobj*: Specifies the tessellation object (created with gluNewTess).
- v: Specifies the location of the vertex.
- data: Specifies an opaque pointer passed back to the user with the vertex callback (as
  specified by gluTessCallback).

DESCRIPTION

gluTessVertex describes a vertex on a polygon that the user is defining. Successive gluTessVertex
calls describe a closed contour. For example, if the user wants to describe a quadrilateral, then
 gluTessVertex should be called four times. gluTessVertex can only be called between
gluBeginPolygon and gluEndPolygon.
data normally points to a structure containing the vertex location, as well as other per−vertex
attributes such as color and normal. This pointer is passed back to the user through the
GLU_VERTEX callback after tessellation (see the "gluTessCallback" reference page).

EXAMPLE

A quadrilateral with a triangular hole in it can be described as follows:

```c
  gluBeginPolygon(tobj);
  gluTessVertex(tobj, v1, v1);
  gluTessVertex(tobj, v2, v2);
  gluTessVertex(tobj, v3, v3);
  gluTessVertex(tobj, v4, v4);
  gluNextContour(tobj, GLU_INTERIOR);
  gluTessVertex(tobj, v5, v5);
  gluTessVertex(tobj, v6, v6);
  gluTessVertex(tobj, v7, v7);
  gluEndPolygon(tobj);
```

SEE ALSO

"glBeginPolygon", "gluNewTess", "gluNextContour", "gluTessCallback"

gluUnProject

NAME

gluUnProject – map window coordinates to object coordinates

C SPECIFICATION

int gluUnProject ( GLdouble winx, GLdouble winy, GLdouble winz, const GLdouble modelMatrix[16],
    const GLdouble projMatrix[16], const GLint viewport[4], GLdouble *objx, GLdouble *objy, GLdouble *objz )

PARAMETERS

- winx, winy, winz: Specify the window coordinates to be mapped.
- modelMatrix: Specifies the modelview matrix (as from a glGetDoublev call).
- projMatrix: Specifies the projection matrix (as from a glGetDoublev call).
- viewport: Specifies the viewport (as from a glGetIntegerv call).
- objx, objy, objz: Returns the computed object coordinates.

DESCRIPTION

gluUnProject maps the specified window coordinates into object coordinates using modelMatrix, projMatrix, and viewport.
The result is stored in objx, objy, and objz. A return value of GL_TRUE indicates success, and GL_FALSE indicates failure.

SEE ALSO

"glGet", "glProject"

Chapter 7

GLX Reference Pages

This chapter contains the reference pages, in alphabetical order, for all the routines comprising the
OpenGL extension to X (GLX). Note that there is a glXIntro page, which gives an overview of OpenGL
in the X Window System; you might want to start with this page.

glXChooseVisual

NAME

glXChooseVisual – return a visual that matches specified attributes
**C SPECIFICATION**

`XVisualInfo* glXChooseVisual( Display *dpy, int screen, int *attribList )`

**PARAMETERS**
- `dpy` Specifies the connection to the X server.
- `screen` Specifies the screen number.
- `attribList` Specifies a list of Boolean attributes and integer attribute/value pairs. The last attribute must be `None`.

**DESCRIPTION**

`glXChooseVisual` returns a pointer to an `XVisualInfo` structure describing the visual that best meets a minimum specification. The Boolean GLX attributes of the visual that is returned will match the specified values, and the integer GLX attributes will meet or exceed the specified minimum values. If all other attributes are equivalent, then TrueColor and PseudoColor visuals have priority over DirectColor and StaticColor visuals, respectively. If no conforming visual exists, `NULL` is returned. To free the data returned by this function, use `XFree`. All Boolean GLX attributes default to `False` except `GLX_USE_GL`, which defaults to `True`. All integer `attribList` attributes are understood to be `None`. Integer attributes are followed immediately by the corresponding desired or minimum value. The list must be terminated with `None`.

The interpretations of the various GLX visual attributes are as follows:
- **GLX_USE_GL** Ignored. Only visuals that can be rendered with GLX are considered.
- **GLX_BUFFER_SIZE** Must be followed by a nonnegative integer that indicates the desired color index buffer size. The smallest index buffer of at least the specified size is preferred. Ignored if `GLX_RGBA` is asserted.
- **GLX_LEVEL** Must be followed by an integer buffer−level specification. This specification is honored exactly. Buffer level zero corresponds to the default frame buffer of the display. Buffer level one is the first overlay frame buffer, level two the second overlay frame buffer, and so on. Negative buffer levels correspond to underlay frame buffers.
- **GLX_RGBA** If present, only TrueColor and DirectColor visuals are considered. Otherwise, only PseudoColor and StaticColor visuals are considered.
- **GLX_DOUBLEBUFFER** If present, only double−buffered visuals are considered. Otherwise, only single−buffered visuals are considered.
- **GLX_STEREO** If present, only stereo visuals are considered. Otherwise, only monoscopic visuals are considered.
- **GLX_AUX_BUFFERS** Must be followed by a nonnegative integer that indicates the desired number of auxiliary buffers. Visuals with the smallest number of auxiliary buffers that meets or exceeds the specified number are preferred.
- **GLX_RED_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, the smallest available red buffer is preferred. Otherwise, the largest available red buffer of at least the minimum size is preferred.
- **GLX_GREEN_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, the smallest available green buffer is preferred. Otherwise, the largest available green buffer of at least the minimum size is preferred.
- **GLX_BLUE_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, the smallest available blue buffer is preferred. Otherwise, the largest available blue buffer of at least the minimum size is preferred.
- **GLX_ALPHA_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, the smallest available alpha buffer is preferred. Otherwise, the largest available alpha buffer of at least the minimum size is preferred.
- **GLX_DEPTH_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, visuals with no depth buffer are preferred. Otherwise, the largest available depth buffer of at least the minimum size is preferred.
- **GLX_STENCIL_SIZE** Must be followed by a nonnegative integer that indicates the desired number of stencil bitplanes. The smallest stencil buffer of at least the specified size is preferred. If the desired value is zero, visuals with no stencil buffer are preferred.
- **GLX_ACCUM_RED_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, visuals with no red accumulation buffer are preferred. Otherwise, the largest possible red accumulation buffer of at least the minimum size is preferred.
- **GLX_ACCUM_GREEN_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, visuals with no green accumulation buffer are preferred. Otherwise, the largest possible green accumulation buffer of at least the minimum size is preferred.
- **GLX_ACCUM_BLUE_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, visuals with no blue accumulation buffer are preferred. Otherwise, the largest possible blue accumulation buffer of at least the minimum size is preferred.
- **GLX_ACCUM_ALPHA_SIZE** Must be followed by a nonnegative minimum size specification. If this value is zero, visuals with no alpha accumulation buffer are preferred. Otherwise, the largest possible alpha accumulation buffer of at least the minimum size is preferred.

**EXAMPLES**

```c
attribList = (GLX_RGBA, GLX_RED_SIZE, 4, GLX_GREEN_SIZE, 4, GLX_BLUE_SIZE, 4, None);
```

Specifies a single−buffered RGB visual in the normal frame buffer, not an overlay or underlay buffer. The returned visual supports at least four bits each of red, green, and blue, and possibly no bits of alpha. It does not support color index mode, double−buffering, or stereo display. It may or may not have one or more auxiliary color buffers, a depth buffer, a stencil buffer, or an accumulation buffer.

**NOTES**

`XVisualInfo` is defined in `Xutil.h`. It is a structure that includes visual, visualID, screen, and depth elements.

`glXChooseVisual` is implemented as a client−side utility using only `XGetVisualInfo` and `glXGetConfig`. Calls to these two routines can be used to implement selection algorithms other than the generic one implemented by `glXChooseVisual`. GLX implementations are strongly discouraged, but not proscribed, from changing the selection algorithm used by `glXChooseVisual`. Therefore, selections may change from release to release of the client−side library. There is no direct filter for picking only visuals that support GLXPixmaps. GLXPixmaps are supported...
subprocess group is equivalent to a process.

ERRORS
NULL is returned if an undefined GLX attribute is encountered in attribList.

SEE ALSO
'glXCreateContext', 'glXGetConfig'

**glXCopyContext**

NAME
glXCopyContext — copy state from one rendering context to another

C SPECIFICATION

```c
void glXCopyContext( Display *dpy, GLXContext src, GLXContext dst, GLuint mask )
```

PARAMETERS

- **dpy**: Specifies the connection to the X server.
- **src**: Specifies the source context.
- **dst**: Specifies the destination context.
- **mask**: Specifies which portions of src state are to be copied to dst.

DESCRIPTION

**glXCopyContext** copies selected groups of state variables from src to dst. mask indicates which groups of state variables are to be copied. mask contains the bitwise OR of the same symbolic names that are passed to the OpenGL command *glPushAttrib*. The single symbolic constant **GL_ALL_ATTRIB_BITS** can be used to copy the maximum possible portion of rendering state.

The copy can be done only if the renderers named by src and dst share an address space. Two rendering contexts share an address space if both are nondirect using the same server, or if both are direct and owned by a single process. Note that in the nondirect case it is not necessary for the calling threads to share an address space, only for their related rendering contexts to share an address space.

Not all values for OpenGL state can be copied. For example, pixel pack and unpack state, render mode state, and select and feedback state are not copied. The state that can be manipulated by OpenGL command **glPushAttrib** is undefined.

NOTES

If src is not the current context for the thread issuing the request, then the state of the src context is undefined.

**SEE ALSO**

'glPushAttrib', 'glXCreateContext', 'glXIsDirect'

**glXCreateContext**

NAME
glXCreateContext — create a new GLX rendering context

C SPECIFICATION

```c
GLXContext glXCreateContext( Display *dpy, XVisualInfo *vis, GLXContext shareList, Bool direct )
```

PARAMETERS

- **dpy**: Specifies the connection to the X server.
- **vis**: Specifies the visual that defines the frame buffer resources available to the rendering context. It is a pointer to an **XVisualInfo** structure, not a visual ID or a pointer to a Visual.
- **shareList**: Specifies the context with which to share display lists. **NULL** indicates that no sharing is to take place.
- **direct**: Specifies whether rendering is to be done with a direct connection to the graphics system if possible (True) or through the X server (False).

DESCRIPTION

**glXCreateContext** creates a GLX rendering context and returns its handle. This context can be used to render into both windows and GLX pixmaps. If **glXCreateContext** fails to create a rendering context, **NULL** is returned.

If direct is True, then a direct rendering context is created if the implementation supports direct rendering and the connection is to an X server that is local. If direct is False, then a rendering context that renders through the X server is always created. Direct rendering provides a performance advantage in some implementations. However, direct rendering contexts cannot be shared outside a single process, and they cannot be used to render to GLX pixmaps.

If shareList is not **NULL**, then all display−list indexes and definitions are shared by context shareList and by the newly created context. An arbitrary number of contexts can share a single display−list space. However, all rendering contexts that share a single display−list space must themselves exist in subprocess groups.
the same address space. Two rendering contexts share an address space if both are nondirect using the
same server, or if both are direct and owned by a single process. Note that in the nondirect case, it is
not necessary for the calling threads to share an address space, only for their related rendering
contexts to share an address space.

NOTES
XVisualInfo is defined in Xutil.h. It is a structure that includes visual, visualID, screen, and depth
elements.
A process is a single execution environment, implemented in a single address space, consisting of one or
more threads.
A thread is one of a set of subprocesses that share a single address space, but maintain separate
program counters, stack spaces, and other related global data. A thread that is the only member of its
subprocess group is equivalent to a process.

ERRORS
NULL is returned if execution fails on the client side.
BadMatch is generated if the context to be created would not share the address space or the screen of
the context specified by shareList.
GLX_Bad_Context is generated if shareList is not a GLX context and is not NULL.
BadAlloc is generated if the server does not have enough resources to allocate the new context.

SEE ALSO
‘glXDestroyContext’, ‘glXGetConfig’, ‘glXIsDirect’, ‘glXMakeCurrent’

glXCreateGLXPixmap

NAME
glXCreateGLXPixmap – create an off-screen GLX rendering area

C SPECIFICATION
void glXCreateGLXPixmap(Display *dpy, XVisualInfo *vis, Pixmap pixmap)

DESCRIPTION
glXCreateGLXPixmap creates an off-screen rendering area and returns its XID. Any GLX
rendering context that was created with respect to vis can be used to render into this off-screen area.
Use glXMakeCurrent to associate the rendering area with a GLX rendering context.
The X pixmap identified by pixmap is used as the front left color buffer of the off-screen rendering
area. All other buffers specified by vis, including color buffers other than the front left buffer, are
created without externally visible names. GLX pixmaps with double-buffering are supported.
However, glXSwapBuffers is ignored by these pixmaps.

Direct rendering contexts cannot be used to render into GLX pixmaps.

NOTES
XVisualInfo is defined in Xutil.h. It is a structure that includes visual, visualID, screen, and depth
elements.

ERRORS
BadMatch is generated if the depth of pixmap does not match the GLX_BUFFER_SIZE value of vis,
or if pixmap was not created with respect to the same screen as vis.
BadValue is generated if vis is not a valid XVisualInfo pointer (e.g., if the GLX implementation does
not support this visual).
BadPixmap is generated if pixmap is not a valid pixmap.
BadAlloc is generated if the server cannot allocate the GLX pixmap.

SEE ALSO
‘glXCreateContext’, ‘glXIsDirect’, ‘glXMakeCurrent’

glXDestroyContext

NAME
glXDestroyContext – destroy a GLX context

C SPECIFICATION
void glXDestroyContext(Display *dpy, GLXContext ctx)

PARAMETERS

dpy Specifies the connection to the X server.
ctx Specifies the GLX context to be destroyed.

DESCRIPTION
If GLX rendering context ctx is not current to any thread, glXDestroyContext destroys it
immediately. Otherwise, ctx is destroyed when it becomes not current to any thread. In either case, the
resource ID referenced by ctx is freed immediately.

ERRORS
GLX_Bad_Context is generated if ctx is not a valid GLX context.

SEE ALSO
‘glXCreateContext’, ‘glXMakeCurrent’
**glXDestroyGLXPixmap**

**NAME**

glXDestroyGLXPixmap — destroy a GLX pixmap

**C SPECIFICATION**

```c
void glXDestroyGLXPixmap( Display *dpy, GLXPixmap pix )
```

**PARAMETERS**

- `dpy` Specifies the connection to the X server.
- `pix` Specifies the GLX pixmap to be destroyed.

**DESCRIPTION**

If GLX pixmap `pix` is not current to any client, `glXDestroyGLXPixmap` destroys it immediately. Otherwise, `pix` is destroyed when it becomes not current to any client. In either case, the resource ID is freed immediately.

**ERRORS**

- `GLX_Bad_Pixmap` is generated if `pix` is not a valid GLX pixmap.

**SEE ALSO**

`'glXCreateGLXPixmap'`, `'glXMakeCurrent'`

---

**glXGetConfig**

**NAME**

glXGetConfig — return information about GLX visuals

**C SPECIFICATION**

```c
int glXGetConfig( Display *dpy, XVisualInfo *vis, int attrib, int *value )
```

**PARAMETERS**

- `dpy` Specifies the connection to the X server.
- `vis` Specifies the visual to be queried. It is a pointer to an `XVisualInfo` structure, not a visual ID or a pointer to a `Visual`.
- `attrib` Specifies the visual attribute to be returned.
- `value` Returns the requested value.

**DESCRIPTION**

`glXGetConfig` sets value to the attrib value of windows or GLX pixmaps created with respect to vis.

`glXGetConfig` returns an error code if it fails for any reason. Otherwise, zero is returned.

**attrib** is one of the following:

- `GLX_USE_GL` True if OpenGL rendering is supported by this visual, False otherwise.
- `GLX_BUFFER_SIZE` of `GLX_RED_SIZE`, `GLX_GREEN_SIZE`, `GLX_BLUE_SIZE`, and `GLX_ALPHA_SIZE`. For color index visuals, `GLX_BUFFER_SIZE` is the size of the color indexes.
- `GLX_LEVEL` Frame buffer level of the visual. Level zero is the default frame buffer. Positive levels correspond to frame buffers that overlay the default buffer, and negative levels correspond to frame buffers that underlay the default buffer.
- `GLX_RGBA` True if color buffers store red, green, blue, and alpha values, False if they store color indexes.
- `GLX_DOUBLEBUFFER` True if color buffers exist in front/back pairs that can be swapped, False otherwise.
- `GLX_STEREO` True if color buffers exist in left/right pairs, False otherwise.
- `GLX_AUX_BUFFERS` Number of auxiliary color buffers that are available. Zero indicates that no auxiliary color buffers exist.
- `GLX_RED_SIZE` Number of bits of red stored in each color buffer. Undefined if `GLX_RGBA` is False.
- `GLX_GREEN_SIZE` Number of bits of green stored in each color buffer. Undefined if `GLX_RGBA` is False.
- `GLX_BLUE_SIZE` Number of bits of blue stored in each color buffer. Undefined if `GLX_RGBA` is False.
- `GLX_ALPHA_SIZE` Number of bits of alpha stored in each color buffer. Undefined if `GLX_RGBA` is False.
- `GLX_DEPTH_SIZE` Number of bits in the depth buffer.
- `GLX_STENCIL_SIZE` Number of bits in the stencil buffer.
- `GLX_ACCUM_RED_SIZE` Number of bits of red stored in the accumulation buffer.
- `GLX_ACCUM_GREEN_SIZE` Number of bits of green stored in the accumulation buffer.
- `GLX_ACCUM_BLUE_SIZE` Number of bits of blue stored in the accumulation buffer.
- `GLX_ACCUM_ALPHA_SIZE` Number of bits of alpha stored in the accumulation buffer.

The X protocol allows a single visual ID to be instantiated with different numbers of bits per pixel. Windows or GLX pixmaps that will be rendered with OpenGL, however, must be instantiated with a color buffer depth of `GLX_BUFFER_SIZE`.

Although a GLX implementation can export many visuals that support OpenGL rendering, it must support at least two. One is an RGBA visual with at least one color buffer, a stencil buffer of at least 1 bit, and a depth buffer of at least 12 bits, and an accumulation buffer. Alpha bitplanes are optional in this visual. However, its color buffer size must be as great as that of the deepest `TrueColor`, `DirectColor`, `PseudoColor`, or `StaticColor` visual supported on level zero, and it must itself be made available on level zero.

The other required visual is a color index one with at least one color buffer, a stencil buffer of at least 1 bit, and a depth buffer of at least 12 bits. This visual must have as many color bitplanes as the deepest `PseudoColor` or `StaticColor` visual supported on level zero, and it must itself be made available on level zero.

Applications are best written to select the visual that most closely meets their requirements. Creating windows or GLX pixmaps with unnecessary buffers can result in reduced rendering performance as well as poor resource allocation.
NOTES

XVisualInfo is defined in Xutil.h. It is a structure that includes visual, visualID, screen, and depth elements.

ERRORS

GLX_NO_EXTENSION is returned if dpy does not support the GLX extension.
GLX_BAD_SCREEN is returned if the screen of vis does not correspond to a screen.
GLX_BAD_ATTRIB is returned if attrib is not a valid GLX attribute. GLX_BAD_VISUAL is returned if vis doesn’t support GLX and an attribute other than GLX_USE_GL is requested.

SEE ALSO

‘glXChooseVisual”, “glXCreateContext”

SEE ALSO

‘glXCreateGLXPixmap”, “glXMakeCurrent”

NAME

glXIntro

NAME

glXIntro – Introduction to OpenGL in the X window system

OVERVIEW

OpenGL is a high−performance 3−D−oriented renderer. It is available in the X window system through the GLX extension. Use glXQueryExtension and glXQueryVersion to establish whether the GLX extension is supported by an X server, and if so, what version is supported. GLX extended servers make a subset of their visuals available for OpenGL rendering. Drawables created with these visuals can also be rendered using the current context and with the renderers of any other X extension that is compatible with all core X visuals. GLX extends drawables with several buffers other than the standard color buffer. These buffers include back and auxiliary color buffers, a depth buffer, a stencil buffer, and a color accumulation buffer. Some or all are included in each visual that supports OpenGL. To render using OpenGL into an X drawable, you must first choose a visual that defines the required OpenGL buffers. glXChooseVisual can be used to simplify selecting a compatible visual. If more control of the selection process is required, use XGetVisualInfo and glXGetConfig to select among all the available visuals. Use the selected visual to create both a GLX context and an X drawable. GLX contexts are created with glXCreateContext, and drawables are created with either XCreateWindow or glXCreateGLXPixmap. Finally, bind the context and the drawable together using glXMakeCurrent. This context/drawable pair becomes the current context and current drawable, and it is used by all OpenGL commands until glXMakeCurrent is called with different arguments. Both core X and OpenGL command streams can be used to operate on the current drawable. The X and OpenGL command streams are not synchronized, however, except at explicitly created boundaries generated by calling glXWaitGL, glXWaitX, XSync, and glFlush.

EXAMPLES

Below is the minimum code required to create an RGBA−format, OpenGL−compatible X window and clear it to yellow. The code is correct, but it does not include any error checking. Return values dpd, vi, cx, cmap, and win should all be tested.

```
#include  <GL/glx.h>
#include  <GL/gl.h>
#include  <unistd.h>

static int attributeList[] = { GLX_RGBA, None };
static Bool swa;
Window win;
GLXContext cx;
XEvent event;

/* get a connection */
dpy = XOpenDisplay(0);
```
/* get an appropriate visual */
vi = glXChooseVisual(dpy, DefaultScreen(dpy), attributeList);
/* create a GL context */
ctx = glXCreateContext(dpy, vi, 0, GL_FALSE);
/* create a color map */
cmap = XCreateColormap(dpy, RootWindow(dpy, vi->screen), vi->visual, AllocNone);
/* create a window */
swa.color_map = cmap;
swa.border_pixel = 0;
swa.event_mask = StructureNotifyMask;
win = XCreateWindow(dpy, RootWindow(dpy, vi->screen), 0, 0, 100, 100, 0, vi->depth, InputOutput, vi->visual, CWBorderPixel|CWColormap|CWEventMask, swa);
XMapWindow(dpy, win);
XtEvent(dpy, event, WaitForNotify, (char*)win);
/* connect the context to the window */
glxMakeCurrent(dpy, win, ctx);
/* clear the buffer */
glClearColor(1,1,0,1);
glClear(GL_COLOR_BUFFER_BIT);
glFlush();
/* wait a while */
sleep(10);
}

NOTES
A color map must be created and passed to XCreateWindow. See the example code above.
A GLX context must be created and attached to an X drawable before OpenGL commands can be executed. OpenGL commands issued while no context/drawable pair is current are ignored.

Exposure events indicate that all buffers associated with the specified window may be damaged and should be repainted. Although certain buffers of some visuals on some systems may never require repainting (the depth buffer, for example), it is incorrect to code assuming that these buffers will not be damaged.

GLX commands manipulate XVisualInfo structures rather than pointers to visuals or visual IDs. XVisualInfo structures contain visual, visualID, screen, and depth elements, as well as other X−specific information.

SEE ALSO

C SPECIFICATION

**glXIsDirect** (Display *dpy, GLXContext ctx)

PARAMETERS

dpy Specifies the connection to the X server.
dctx Specifies the GLX context that is being queried.

DESCRIPTION

glxIsDirect returns True if ctx is a direct rendering context, False otherwise. Direct rendering contexts pass rendering commands directly from the calling process's address space to the rendering system, bypassing the X server. Nondirect rendering contexts pass all rendering commands to the X server.

ERRORS

GLX_Bad_Context is generated if ctx is not a valid GLX context.

SEE ALSO
"glXCreateContext"

C SPECIFICATION

**glXMakeCurrent**

NAME

glxMakeCurrent – attach a GLX context to a window or a GLX pixmap

C SPECIFICATION

**glXMakeCurrent** (Display *dpy, GLXDrawable drawable, GLXContext ctx)

PARAMETERS

dpy Specifies the connection to the X server.
drawable Specifies a GLX drawable. Must be either an X window ID or a GLX pixmap ID.
dctx Specifies a GLX rendering context that is to be attached to drawable

DESCRIPTION

glxMakeCurrent does two things: It makes ctx the current GLX rendering context of the calling thread, replacing the previously current context if there was one, and it attaches ctx to a GLX drawable, either a window or a GLX pixmap. As a result of these two actions, subsequent OpenGL rendering calls use rendering context ctx to modify GLX drawable drawable. Because glxMakeCurrent always replaces the current rendering context with ctx, there can be only one current context per thread.

Pending commands to the previous context, if any, are flushed before it is released. The first time ctx is made current to any thread, its viewport is set to the full size of drawable. Subsequent calls by any thread to glxMakeCurrent with ctx have no effect on its viewport.

To release the current context without assigning a new one, call glxMakeCurrent with drawable and ctx set to None and NULL respectively.
**NOTES**

A process is a single-execution environment, implemented in a single address space, consisting of one or more threads. A thread is one of a set of subprocesses that share a single address space, but maintain separate program counters, stack spaces, and other related global data. A thread that is the only member of its subprocess group is equivalent to a process.

**ERRORS**

- BadMatch is generated if drawable was not created with the same X screen and visual as ctx. It is also generated if drawable is None and ctx is not None.
- BadAccess is generated if ctx was current to another thread at the time glXMakeCurrent was called.
- GLX_Bad_Drawable is generated if drawable is not a valid GLX drawable.
- GLX_Bad_Context is generated if ctx is not a valid GLX context.
- GLX_Bad_Context_State is generated if the rendering context current to the calling thread has OpenGL renderer state GL_FEEDBACK or GL_SELECT.
- GLX_Bad_Current_Window is generated if there are pending OpenGL commands for the previous context and the current drawable is a window that is no longer valid.
- BadAlloc may be generated if the server has delayed allocation of ancillary buffers until glXMakeCurrent is called, only to find that it has insufficient resources to complete the allocation.

**SEE ALSO**

- "glXCreateContext", "glXCreateGLXPixmap"

### glXQueryExtension

**NAME**

glXQueryExtension — indicate whether the GLX extension is supported

**C SPECIFICATION**

```c
Bool glXQueryExtension( Display *dpy, *errorBase, *eventBase)
```

**PARAMETERS**

- dpy: Specifies the connection to the X server.
- errorBase: Returns the base error code of the GLX server extension.
- eventBase: Returns the base event code of the GLX server extension.

**DESCRIPTION**

glXQueryExtension returns True if the X server of connection dpy supports the GLX extension, False otherwise. If True is returned, then errorBase and eventBase return the error base and event base of the GLX extension. Otherwise, errorBase and eventBase are unchanged.

**ERRORS**

- glXQueryExtension returns False if it fails, True otherwise. major and minor are not updated when False is returned.

**SEE ALSO**

- "glXQueryExtension"

### glXSwapBuffers

**NAME**

glXSwapBuffers — make back buffer visible

**C SPECIFICATION**

```c
void glXSwapBuffers( Display *dpy, GLXDrawable drawable )
```
PARAMETERS
dpy Specifies the connection to the X server.
drawable Specifies the window whose buffers are to be swapped.

DESCRIPTION
glxXSwapBuffers promotes the contents of the back buffer of drawable to become the contents of the front buffer of drawable. The contents of the back buffer then become undefined. The update typically takes place during the vertical retrace of the monitor, rather than immediately after glXSwapBuffers is called. All GLX rendering contexts share the same notion of which are front buffers and which are back buffers.

An implicit glFlush is done by glXSwapBuffers before it returns. Subsequent OpenGL commands can be issued immediately after calling glXSwapBuffers, but are not executed until the buffer exchange is completed.

If drawable was not created with respect to a double-buffered visual, glXSwapBuffers has no effect, and no error is generated.

NOTES
Synchronization of multiple GLX contexts rendering to the same double-buffered window is the responsibility of the clients. The X Synchronization Extension can be used to facilitate such cooperation.

ERRORS
GLX_Bad_Drawable is generated if drawable is not a valid GLX drawable.

GLX_Bad_Current_Window is generated if the drawable associated with the current context of the calling thread is a window, and that window is no longer valid.

SEE ALSO
"glFlush", "glXUseXFont"

glXUseXFont

NAME
glxXUseXFont – create bitmap display lists from an X font

C SPECIFICATION
void glXUseXFont( Font font, int first, int count, int listBase )

PARAMETERS
font Specifies the font from which character glyphs are to be taken.
first Specifies the index of the first glyph to be taken.
count Specifies the number of glyphs to be taken.
listBase Specifies the index of the first display list to be generated.

DESCRIPTION
glxXUseXFont generates count display lists, named listBase through listBase + count – 1, each containing a single glBitmap command. The parameters of the glBitmap command of display list listBase + i are derived from glyph first + i. Bitmap parameters xorig, yorig, width, and height are computed from font metrics as descent−1, −lbearing+rbearing, and ascender−descent, respectively. xmove is taken from the glyph's width metric, and ymove is set to zero. Finally, the glyph's image is converted to the appropriate format for glBitmap.

Using glXUseXFont may be more efficient than accessing the X font and generating the display lists explicitly, both because the display lists are created on the server without requiring a round trip of the glyph data, and because the server may choose to delay the creation of each bitmap until it is accessed. Empty display lists are created for all glyphs that are requested and are not defined in font. glXUseXFont is ignored if there is no current GLX context.

ERRORS
BadFont is generated if font is not a valid font.

GLX_Bad_Context_State is generated if the current GLX context is in display-list construction mode.

GLX_Bad_Current_Window is generated if the drawable associated with the current context of the calling thread is a window, and that window is no longer valid.

SEE ALSO
"glBitmap", "glXMakeCurrent"

glXWaitGL

NAME
glxWaitGL – complete GL execution prior to subsequent X calls

C SPECIFICATION
void glXWaitGL( void )

DESCRIPTION
OpenGL rendering calls made prior to glXWaitGL are guaranteed to be executed before X rendering calls made after glXWaitGL. Although this same result can be achieved using glFinish, glXWaitGL does not require a round trip to the server, and it is therefore more efficient in cases where client and server are on separate machines.

glXWaitGL is ignored if there is no current GLX context.

NOTES
glxXWaitGL may or may not flush the X stream.

ERRORS
GLX_Bad_Current_Window is generated if the drawable associated with the current context of the calling thread is a window, and that window is no longer valid.
glXWaitX

NAME

glXWaitX -- complete X execution prior to subsequent OpenGL calls

C SPECIFICATION

void glXWaitX ( void )

DESCRIPTION

X rendering calls made prior to glXWaitX are guaranteed to be executed before OpenGL rendering calls made after glXWaitX. Although this same result can be achieved using XSync, glXWaitX does not require a round trip to the server, and it is therefore more efficient in cases where client and server are on separate machines.

glXWaitX is ignored if there is no current GLX context.

NOTES

glXWaitX may or may not flush the OpenGL stream.

ERRORS

GLX_Bad_Current_Window is generated if the drawable associated with the current context of the calling thread is a window, and that window is no longer valid.

SEE ALSO

'glFinish', 'glFlush', 'glXWaitGL', XSync