OpenGL® SC 2.0 is a safety-critical subset of **OpenGL® ES** 2.0, which a software interface to graphics hardware for producing high-quality color images of three-dimensional objects.

- **[n.n.n]** refers to sections and tables in the OpenGL SC 2.0 specification.
- **[n.n.n]** refers to sections in the OpenGL ES Shading Language 1.0 specification.
- In descriptions, curly braces {} mean "one of," and square braces [] mean "optional."
- Specifications are available at www.khronos.org/registry/glsc/

Khronos strongly encourages OpenGL SC implementations to also support EGL, but some implementations may provide alternate, platform- or vendor-specific APIs with similar functionality. Specifically, OpenGL SC is defined targeting EGL 1.4 with the EGL EXT-create context robustness and EGL KHR surfaceless context extensions.

OpenGL SC Command Syntax [2.3]

For brevity, the OpenGL documentation and this reference may omit the standard prefixes.
The actual names are of the forms: glFunctionName(), GL_CONSTANT, GLtype

OpenGL SC commands are formed from a return type, a name, and optionally a type letter i for 32-bit int, or f for 32-bit float, as shown by the prototype below:

return-type **Name**[1234][if][v] (*[args ,] T arg1 , . . . , T argN [, args]*);

The argument type T and the number *N* of arguments may be indicated by the command name suffixes.

N is 1, 2, 3, or 4 if present, or else corresponds to the type letters. If "v" is present, an array of *N* items is passed by a pointer.

Buffer Objects [2.10]

Buffer objects hold vertex array data or indices in high-performance server memory.

void **GenBuffers**(sizei *n*, uint **buffers*);

Creating and Binding Buffer Objects

void **BindBuffer**(enum *target*, uint *buffer*);
target: ARRAY_BUFFER, ELEMENT_ ARRAY_BUFFER

Creating Buffer Object Data Stores

void **BufferData**(enum *target*, sizeiptr *size*, const void **data*, enum *usage*);
target: ARRAY_BUFFER, ELEMENT_ ARRAY_BUFFER
usage: STATIC_DRAW, STREAM_DRAW, DYNAMIC_DRAW

Updating Buffer Object Data Stores

void **BufferSubData**(enum *target*, intptr *offset*, sizeiptr *size*, const void **data*);
target: ARRAY_BUFFER, ELEMENT_ ARRAY_BUFFER

Buffer Object Queries [6.1.6, 6.1.3]

void **GetBufferParameteriv**(enum *target*, enum *value*, T *data*);
target: ARRAY_BUFFER, ELEMENT_ ARRAY_BUFFER
value: BUFFER_SIZE, BUFFER_USAGE

Shaders and Programs

Program Objects [2.11.1]

uint **CreateProgram**(void);

uint **ProgramBinary**(uint *program*, enum *binaryformat*, const void **binary*, sizei *length*);

void **UseProgram**(uint *program*);

Shader Variables [2.11.2]

Vertex Attributes

int **GetAttribLocation**(uint *program*, const char **name*);

Uniform Variables

int **GetUniformLocation**(uint *program*, const char **name*);

void **Uniform{1234}{if}**(int *location*, T *value*);

void **Uniform{1234}{if}v**(int *location*, sizei *count*, T *value*);

void **UniformMatrix{234}fv**(int *location*, sizei *count*, boolean *transpose*, const float **value*);
transpose: FALSE

Shader Queries

Shader Queries [6.1.5]

void **GetVertexAttribfv**(uint *index*, enum *pname*, float **params*);
pname: CURRENT_VERTEX_ATTRIB , VERTEX_ATTRIB_ARRAY_*x* (where *x* may be BUFFER_BINDING, ENABLED, SIZE, STRIDE, TYPE, NORMALIZED)

void **GetVertexAttribiv**(uint *index*, enum *pname*, int **params*);
pname: CURRENT_VERTEX_ATTRIB , VERTEX_ATTRIB_ARRAY_*x* (where *x* may be BUFFER_BINDING, ENABLED, SIZE, STRIDE, TYPE, NORMALIZED)

void **GetVertexAttribPointerv**(uint *index*, enum *pname*, void ***pointer*);
pname: VERTEX_ATTRIB_ARRAY_POINTER

void **GetnUniformfv**(uint *program*, int *location*, sizei *bufSize*, float **params*)

void **GetnUniformiv**(uint *program*, int *location*, sizei *bufSize*, int **params*)

Program Queries [6.1.8]

void **GetProgramiv**(uint *program*, enum *pname*, int **params*);
pname: LINK_STATUS

Viewport and Clipping

Controlling the Viewport [2.13.1]

void **DepthRangef**(float *n*, float *f*);

void **Viewport**(int *x*, int *y*, sizei *w*, sizei *h*);

Pixel Rectangles [3.6, 4.3]

void **PixelStorei**(enum *pname*, T *param*);
pname: UNPACK_ALIGNMENT

Rasterization [3]

Points [3.3]

Point size is taken from the shader builtin **gl_PointSize** and clamped to the implementation-dependent point size range.

Line Segments [3.4]

void **LineWidth**(float *width*);

Polygons [3.5]

void **FrontFace**(enum *dir*);
dir: CCW, CW

void **CullFace**(enum *mode*);
mode: FRONT, BACK, FRONT_AND_BACK

Enable/Disable(CULL_FACE)

void **PolygonOffset**(float *factor*, float *units*);

Enable/Disable(POLYGON_OFFSET_FILL)

GL Data Types [2.3]

GL types are not C types.

GL Type	Minimum Bit Width	Description
boolean	1	Boolean
byte	8	Signed binary integer
ubyte	8	Unsigned binary integer
char	8	Characters making up strings
short	16	Signed 2's complement binary integer
ushort	16	Unsigned binary integer
int	32	Signed 2's complement binary integer
uint	32	Unsigned binary integer
sizei	32	Non-negative binary integer size
enum	32	Enumerated binary integer value
intptr	*ptrbits*	Signed 2's complement binary integer
sizeiptr	*ptrbits*	Non-negative binary integer size
bitfield	32	Bit field
float	32	Floating-point value

Errors and Status Reset

Errors [2.5]

enum **GetError**(void); //Returns one of:

INVALID_ENUM	Enum argument out of range
INVALID_FRAMEBUFFER_OPERATION	Framebuffer is incomplete
INVALID_VALUE	Numeric argument out of range
INVALID_OPERATION	Operation illegal in current state
OUT_OF_MEMORY	Not enough memory
CONTEXT_LOST	Context has been lost
NO_ERROR	No error encountered

Graphics Reset Recovery [2.6]

enum **GetGraphicsResetStatus**(void); //Returns one of:

NO_ERROR	GL context has not been in a reset state since the last call
GUILTY_CONTEXT_RESET	A reset has been detected that is attributable to the current GL context
INNOCENT_CONTEXT_RESET	A reset has been detected that is not attributable to the current GL context
UNKNOWN_CONTEXT_RESET	A graphics reset has been detected whose cause is unknown

Vertices

Current Vertex State [2.8]

void **VertexAttrib{1234}{f}**(uint *index*, T *values*);
index: [0, MAX_VERTEX_ATTRIBS - 1]

void **VertexAttrib{1234}{f}v**(uint *index*, T *values*);
index: [0, MAX_VERTEX_ATTRIBS - 1]

Vertex Arrays [2.9]

void **VertexAttribPointer**(uint *index*, int *size*, enum *type*, boolean *normalized*, sizei *stride*, const void **pointer*);
type: BYTE, UNSIGNED_BYTE, SHORT, UNSIGNED_SHORT, FLOAT
index: [0, MAX_VERTEX_ATTRIBS - 1]

void **EnableVertexAttribArray**(uint *index*);

void **DisableVertexAttribArray**(uint *index*);
index: [0, MAX_VERTEX_ATTRIBS - 1]

void **DrawArrays**(enum *mode*, int *first*, sizei *count*);

void **DrawRangeElements**(enum *mode*, unit *start*, uint *end*, sizei *count*, enum *type*, const void **indices*);
mode: POINTS, LINE_STRIP, LINE_LOOP, LINES, TRIANGLE_STRIP, TRIANGLE_FAN, TRIANGLES
type: UNSIGNED_SHORT

Texturing [3.7]

Shaders support texturing using at least MAX_VERTEX_TEXTURE_IMAGE_UNITS images for vertex shaders and at least MAX_TEXTURE_IMAGE_UNITS images for fragment shaders.

void **ActiveTexture**(enum *texture*);
texture: TEXTURE*i* where *i* = [0..MAX_COMBINED_TEXTURE_IMAGE_UNITS-1]

Texture Image Specification [3.7.1]

void **TexStorage2D**(enum *target*, int *level*, int *internalformat*, sizei *width*, sizei *height*);
target: TEXTURE_2D
internalformat: (Table 3.4) R8, RG8, RGB8, RGBA8, RGBA4, RGB5_A1, RGB565

Conversion from RGBA pixel components to internal texture components:

Base Internal Format	RGBA	Internal Components
RGB	R, G, B	R, G, B
RGBA	R, G, B, A	R, G, B, A

Alt. Texture Image Specification Commands [3.7.2]

Texture images may also be specified using image data taken directly from the framebuffer, and rectangular subregions of existing texture images may be respecified.

void **TexSubImage2D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, sizei *width*, sizei *height*, enum *format*, enum *type*, void **data*);
target: TEXTURE_2D
format: RGBA, RGB, RG, RED
type: UNSIGNED_BYTE, UNSIGNED_SHORT_4_4_4_4, UNSIGNED_SHORT_5_5_5_1, UNSIGNED_SHORT_5_6_5
Note: The internal format must match the type.

Compressed Texture Images [3.7.3]

void **CompressedTexSubImage2D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, sizei *width*, sizei *height*, enum *format*, sizei *imageSize*, void **data*);
target and *internalformat*: *See TexSubImage2D*

Texture Parameters [3.7.4]

void **TexParameter{if}**(enum *target*, enum *pname*, T *param*);

void **TexParameter{if}v**(enum *target*, enum *pname*, T *params*);
target: TEXTURE_2D
pname: TEXTURE_WRAP_{S, T}, TEXTURE_{MIN, MAG}_FILTER

Manual Mipmap Generation [3.7.10]

void **GenerateMipmap**(enum *target*);
target: TEXTURE_2D

Texture Objects [3.7.12]

void **BindTexture**(enum *target*, uint *texture*);
target: TEXTURE_2D

void **GenTextures**(sizei *n*, uint **textures*);

Enumerated Queries [6.1.3]

void **GetTexParameter{if}v**(enum *target*, enum *value*, T *data*);
target: TEXTURE_2D, TEXTURE_CUBE_MAP
value: TEXTURE_WRAP_{S, T}, TEXTURE_{MIN, MAG}_FILTER

Reading Pixels [4.3.1]

void **ReadnPixels**(int *x*, int *y*, sizei *width*, sizei *height*, enum *format*, enum *type*, sizei *bufSize*, void **data*);
format: RGBA
type: UNSIGNED_BYTE

Note: ReadnPixels() also accepts a queriable implementation-defined format/type combination.

Per-Fragment Operations

Scissor Test [4.1.2]

Enable/**Disable**(SCISSOR_TEST)

void **Scissor**(int *left*, int *bottom*, sizei *width*, sizei *height*);

Multisample Fragment Operations [4.1.3]

Enable/**Disable**(*cap*)
cap: SAMPLE_ALPHA_TO_COVERAGE, SAMPLE_COVERAGE

void **SampleCoverage**(float *value*, boolean *invert*);

Stencil Test [4.1.4]

Enable/**Disable**(STENCIL_TEST)

void **StencilFunc**(enum *func*, int *ref*, uint *mask*);

void **StencilFuncSeparate**(enum *face*, enum *func*, int *ref*, uint *mask*);

void **StencilOp**(enum *sfail*, enum *dpfail*, enum *dppass*);

void **StencilOpSeparate**(enum *face*, enum *sfail*, enum *dpfail*, enum *dppass*);
face: FRONT, BACK, FRONT_AND_BACK
sfail, dpfail, and *dppass*: KEEP, ZERO, REPLACE, INCR, DECR, INVERT, INCR_WRAP, DECR_WRAP
func: NEVER, ALWAYS, LESS, LEQUAL, EQUAL, GREATER, GEQUAL, NOTEQUAL

Depth Buffer Test [4.1.5]

Enable/**Disable**(DEPTH_TEST)

void **DepthFunc**(enum *func*);
func: NEVER, ALWAYS, LESS, LEQUAL, EQUAL, GREATER, GEQUAL, NOTEQUAL

Blending [4.1.6]

Enable/**Disable**(BLEND)

void **BlendEquation**(enum *mode*);
mode: FUNC_ADD, FUNC_SUBTRACT, FUNC_REVERSE_SUBTRACT

void **BlendEquationSeparate**(enum *modeRGB*, enum *modeAlpha*);
modeRGB and *modeAlpha*: FUNC_ADD, FUNC_SUBTRACT, FUNC_REVERSE_SUBTRACT

void **BlendFuncSeparate**(enum *srcRGB*, enum *dstRGB*, enum *srcAlpha*, enum *dstAlpha*);

void **BlendFunc**(enum *src*, enum *dst*);
dst, dstRGB, and *dstAlpha*: ZERO, ONE, [ONE_MINUS_]SRC_COLOR, [ONE_MINUS_]DST_COLOR, [ONE_MINUS_]SRC_ALPHA, [ONE_MINUS_]DST_ALPHA, [ONE_MINUS_]CONSTANT_COLOR, [ONE_MINUS_]CONSTANT_ALPHA
src, srcRGB, srcAlpha: same for *dst*, plus SRC_ALPHA_SATURATE

void **BlendColor**(float *red*, float *green*, float *blue*, float *alpha*);

Dithering [4.1.7]

Enable/**Disable**(DITHER)

Whole Framebuffer Operations

Fine Control of Buffer Updates [4.2.2]

void **ColorMask**(boolean *r*, boolean *g*, boolean *b*, boolean *a*);

void **DepthMask**(boolean *mask*);

void **StencilMask**(uint *mask*);

void **StencilMaskSeparate**(enum *face*, uint *mask*);
face: FRONT, BACK, FRONT_AND_BACK

Clearing the Buffers [4.2.3]

void **Clear**(bitfield *buf*);
buf: Bitwise OR of COLOR_BUFFER_BIT, DEPTH_BUFFER_BIT, STENCIL_BUFFER_BIT

void **ClearColor**(float *r*, float *g*, float *b*, float *a*);

void **ClearDepthf**(float *d*);

void **ClearStencil**(int *s*);

Framebuffer Objects

Binding & Managing Framebuffer Objects [4.4.1]

void **BindFramebuffer**(enum *target*, uint *framebuffer*);
target: FRAMEBUFFER

void **GenFramebuffers**(sizei *n*, uint **framebuffers*);

Renderbuffer Objects [4.4.3]

void **BindRenderbuffer**(enum *target*, uint *renderbuffer*);
target: RENDERBUFFER

void **GenRenderbuffers**(sizei *n*, uint **renderbuffers*);

void **RenderbufferStorage**(enum *target*, enum *internalformat*, sizei *width*, sizei *height*);
target: RENDERBUFFER
internalformat: DEPTH_COMPONENT16, RGBA4, RGB5_A1, RGB565, STENCIL_INDEX8

Attaching Renderbuffer Images to Framebuffer

void **FramebufferRenderbuffer**(enum *target*, enum *attachment*, enum *renderbuffertarget*, uint *renderbuffer*);
target: FRAMEBUFFER
attachment: COLOR_ATTACHMENT0, DEPTH_ATTACHMENT, STENCIL_ATTACHMENT
renderbuffertarget: RENDERBUFFER

Attaching Texture Images to a Framebuffer

void **FramebufferTexture2D**(enum *target*, enum *attachment*, enum *textarget*, uint *texture*, int *level*);
textarget: TEXTURE_2D
target: FRAMEBUFFER
attachment: COLOR_ATTACHMENT, DEPTH_ATTACHMENT, STENCIL_ATTACHMENT

Framebuffer Completeness [4.4.5]

enum **CheckFramebufferStatus**(enum *target*);
target: FRAMEBUFFER
returns: FRAMEBUFFER_COMPLETE or a constant indicating which value violates framebuffer completeness

Framebuffer Object Queries [6.1.3, 6.1.7]

void **GetFramebufferAttachmentParameteriv**(enum *target*, enum *attachment*, enum *pname*, int **params*);
target: FRAMEBUFFER
attachment: COLOR_ATTACHMENT0, DEPTH_ATTACHMENT, STENCIL_ATTACHMENT
pname: FRAMEBUFFER_ATTACHMENT_OBJECT_TYPE, FRAMEBUFFER_ATTACHMENT_OBJECT_NAME, FRAMEBUFFER_ATTACHMENT_TEXTURE_LEVEL

Renderbuffer Object Queries [6.1.3, 6.1.7]

void **GetRenderbufferParameteriv**(enum *target*, enum *pname*, int **params*);
target: RENDERBUFFER
pname: RENDERBUFFER_*x* (where *x* may be WIDTH, HEIGHT, RED_SIZE, GREEN_SIZE, BLUE_SIZE, ALPHA_SIZE, DEPTH_SIZE, STENCIL_SIZE, INTERNAL_FORMAT)

Special Functions

Flush and Finish [5.1]

Flush guarantees that commands issued so far will eventually complete. **Finish** blocks until all commands issued so far have completed.

void **Flush**(void);

void **Finish**(void);

Hints [5.2]

Hint controls certain aspects of GL behavior.

void **Hint**(enum *target*, enum *hint*);
target: GENERATE_MIPMAP_HINT
hint: FASTEST, NICEST, DONT_CARE

State and State Requests

A complete list of symbolic constants for states is shown in the tables in [6.2].

Simple Queries [6.1.1]

void **GetBooleanv**(enum *value*, boolean **data*);

void **GetIntegerv**(enum *value*, int **data*);

void **GetFloatv**(enum *value*, float **data*);

boolean **IsEnabled**(enum *value*);

Pointer and String Queries [6.1.4]

ubyte ***GetString**(enum *name*);
name: VENDOR, RENDERER, VERSION, SHADING_LANGUAGE_VERSION, EXTENSIONS

FInd specifications, conformant product listings, and other resources at khronos.org/openglsc/

The OpenGL® ES Shading Language is two closely-related languages which are used to create shaders for the vertex and fragment processors contained in the OpenGL ES processing pipeline.

[n.n.n] and **[Table n.n]** refer to sections and tables in the OpenGL ES Shading Language 1.0 specification at www.opengl.org/registry/gles

Types [4.1]

A shader can aggregate these using arrays and structures to build more complex types. There are no pointer types.

Basic Types

void	no function return value or empty parameter list
bool	Boolean
int	signed integer
float	floating scalar
vec2, vec3, vec4	n-component floating point vector
bvec2, bvec3, bvec4	Boolean vector
ivec2, ivec3, ivec4	signed integer vector
mat2, mat3, mat4	2x2, 3x3, 4x4 float matrix
sampler2D	access a 2D texture
samplerCube	access cube mapped texture

Structures and Arrays [4.1.8, 4.1.9]

Structures	**struct** *type-name* {
	  members
	} *struct-name*[]; // optional variable declaration, // optionally an array

Arrays	**float** foo[3]; * structures and blocks can be arrays * only 1-dimensional arrays supported * structure members can be arrays

Operators and Expressions

Operators [5.1]

Numbered in order of precedence. The relational and equality operators > < <= >= == != evaluate to a Boolean. To compare vectors component-wise, use functions such as lessThan(), equal(), etc.

	Operator	Description	Associativity
1.	( )	parenthetical grouping	N/A
2.	[ ] ( ) . ++ --	array subscript function call & constructor structure field or method selector, swizzler postfix increment and decrement	L - R
3.	++ -- + - !	prefix increment and decrement unary	R - L
4.	* /	multiplicative	L - R
5.	+ -	additive	L - R
7.	< > <= >=	relational	L - R
8.	== !=	equality	L - R
12.	&&	logical and	L - R
13.	^^	logical exclusive or	L - R
14.	| |	logical inclusive or	L - R
15.	? :	selection (Selects one entire operand. Use mix() to select individual components of vectors.)	L - R
16.	= += -= *= /=	assignment arithmetic assignments	L - R
17.	,	sequence	L - R

Vector Components [5.5]

In addition to array numeric subscript syntax, names of vector components are denoted by a single letter. Components can be swizzled and replicated, e.g.: pos.xx, pos.zy

{x, y, z, w}	Use when accessing vectors that represent points or normals
{r, g, b, a}	Use when accessing vectors that represent colors
{s, t, p, q}	Use when accessing vectors that represent texture coordinates

Preprocessor [3.4]

Preprocessor Directives

The number sign (#) can be immediately preceded or followed in its line by spaces or horizontal tabs.

 # #define #undef #if #ifdef #ifndef #else
#elif #endif #error #pragma #extension #version #line

Examples of Preprocessor Directives

- "#version 100" in a shader program specifies that the program is written in GLSL ES version 1.00. It is optional. If used, it must occur before anything else in the program other than whitespace or comments.
- #extension *extension_name* : *behavior*, where *behavior* can be require, enable, warn, or disable; and where *extension_name is* the extension supported by the compiler

Predefined Macros

__LINE__	Decimal integer constant that is one more than the number of preceding new-lines in the current source string
__FILE__	Decimal integer constant that says which source string number is currently being processed.
__VERSION__	Decimal integer, e.g.: 100
GL_ES	Defined and set to integer 1 if running on an OpenGL-ES Shading Language.
GL_FRAGMENT_PRECISION_HIGH	1 if highp is supported in the fragment language, else undefined **[4.5.4]**

Qualifiers

Storage Qualifiers [4.3]

Variable declarations may be preceded by one storage qualifier.

none	(Default) local read/write memory, or input parameter
const	Compile-time constant, or read-only function parameter
attribute	Linkage between a vertex shader and OpenGL ES for per-vertex data
uniform	Value does not change across the primitive being processed, uniforms form the linkage between a shader, OpenGL ES, and the application
varying	Linkage between a vertex shader and fragment shader for interpolated data

Uniform [4.3.4]

Use to declare global variables whose values are the same across the entire primitive being processed. All uniform variables are read-only. Use uniform qualifiers with any basic data types, to declare a variable whose type is a structure, or an array of any of these. For example:

uniform **vec4** lightPosition;

Varying [4.3.5]

The varying qualifier can be used only with the data types float, vec2, vec3, vec4, mat2, mat3, mat4, or arrays of these. Structures cannot be varying. Varying variables are required to have global scope. Declaration is as follows:

varying **vec3** normal;

Parameter Qualifiers [4.4]

Input values are copied in at function call time, output values are copied out at function return time.

none	(Default) same as **in**
in	For function parameters passed into a function
out	For function parameters passed back out of a function, but not initialized for use when passed in
inout	For function parameters passed both into and out of a function

Precision and Precision Qualifiers [4.5]

Any floating point, integer, or sampler declaration can have the type preceded by one of these precision qualifiers:

highp	Satisfies minimum requirements for the vertex language. Optional in the fragment language.
mediump	Satisfies minimum requirements for the fragment language. Its range and precision is between that provided by **lowp** and **highp**.
lowp	Range and precision can be less than **mediump**, but still represents all color values for any color channel.

For example:

```
lowp float color;
varying mediump vec2 Coord;
lowp ivec2 foo(lowp mat3);
highp mat4 m;
```

Ranges & precisions for precision qualifiers (FP=floating point):

	FP Range	FP Magnitude Range	FP Precision	Integer Range
highp	$(-2^{62}, 2^{62})$	$(2^{-62}, 2^{62})$	Relative 2^{-16}	$(-2^{16}, 2^{16})$
mediump	$(-2^{14}, 2^{14})$	$(2^{-14}, 2^{14})$	Relative 2^{-10}	$(-2^{10}, 2^{10})$
lowp	$(-2, 2)$	$(2^{-8}, 2)$	Absolute 2^{-8}	$(-2^{8}, 2^{8})$

A precision statement establishes a default precision qualifier for subsequent int, float, and sampler declarations, e.g.:

precision **highp** int;

Invariant Qualifiers Examples [4.6]

#pragma STDGL invariant(all)	Force all output variables to be invariant
invariant gl_Position;	Qualify a previously declared variable
invariant varying mediump vec3 Color;	Qualify as part of a variable declaration

Order of Qualification [4.7]

When multiple qualifications are present, they must follow a strict order. This order is as follows.

invariant, storage, precision
storage, parameter, precision

Aggregate Operations and Constructors

Matrix Constructor Examples [5.4]

```
mat2(float)                    // init diagonal
mat2(vec2, vec2);              // column-major order
mat2(float, float,
     float, float);            // column-major order
```

Structure Constructor Example [5.4.3]

```
struct light {float intensity; vec3 pos; };
light lightVar = light(3.0, vec3(1.0, 2.0, 3.0));
```

Matrix Components [5.6]

Access components of a matrix with array subscripting syntax. For example:

```
mat4 m;              // m represents a matrix
m[1] = vec4(2.0);    // sets second column to all 2.0
m[0][0] = 1.0;       // sets upper left element to 1.0
m[2][3] = 2.0;       // sets 4th element of 3rd column to 2.0
```

Examples of operations on matrices and vectors:

```
m = f * m;           // scalar * matrix component-wise
v = f * v;           // scalar * vector component-wise
v = v * v;           // vector * vector component-wise
m = m +/- m;         // matrix component-wise addition/subtraction
m = m * m;           // linear algebraic multiply
m = v * m;           // row vector * matrix linear algebraic multiply
m = m * v;           // matrix * column vector linear algebraic multiply
f = dot(v, v);       // vector dot product
v = cross(v, v);     // vector cross product
m = matrixCompMult(m, m);   // component-wise multiply
```

Structure Operations [5.7]

Select structure fields using the period (.) operator. Other operators include:

.	field selector
== !=	equality
=	assignment

Array Operations [4.1.9]

Array elements are accessed using the array subscript operator "[ ]". For example:

```
diffuseColor += lightIntensity[3] * NdotL;
```

Built-In Inputs, Outputs, and Constants [7]

Output Special Variables may be read back after writing. Input Special Variables are read-only.
All Special Variables have global scope.

Vertex Shader Special Variables [7.1]

Outputs:

Variable	Description	Units or coordinate system
highp vec4 gl_Position;	transformed vertex position	clip coordinates
mediump float gl_PointSize;	transformed point size (point rasterization only)	pixels

Fragment Shader Special Variables [7.2]

Fragment shaders may write to **gl_FragColor** or to one or more elements of **gl_FragData[]**, but not both.
The size of the **gl_FragData** array is given by the built-in constant **gl_MaxDrawBuffers**.

Inputs:

Variable	Description	Units or coordinate system
mediump vec4 gl_FragCoord;	fragment position within frame buffer	window coordinates
bool gl_FrontFacing;	fragment belongs to a front-facing primitive	Boolean
mediump int gl_PointCoord;	fragment position within a point (point rasterization only)	0.0 to 1.0 for each component

Outputs:

Variable	Description	Units or coordinate system
mediump vec4 gl_FragColor;	fragment color	RGBA color
mediump vec4 gl_FragData[*n*]	fragment color for color attachment *n*	RGBA color

Built-In Constants With Minimum Values [Appendix F7]

Built-in Constant	Minimum value
const mediump int gl_MaxVertexAttribs	8
const mediump int gl_MaxVertexUniformVectors	128
const mediump int gl_MaxVaryingVectors	8
const mediump int gl_MaxVertexTextureImageUnits	0
const mediump int gl_MaxCombinedTextureImageUnits	8
const mediump int gl_MaxTextureImageUnits	8
const mediump int gl_MaxFragmentUniformVectors	16
const mediump int gl_MaxDrawBuffers	1

Built-In Uniform State [7.5]

Specifies depth range in window coordinates. If an implementation does not support highp precision in the fragment language, and state is listed as highp, then that state will only be available as mediump in the fragment language.

```
struct gl_DepthRangeParameters {
  highp float near;   // n
  highp float far;    // f
  highp float diff;   // f - n
};

uniform gl_DepthRangeParameters gl_DepthRange;
```

Built-In Functions

Angle & Trigonometry Functions [8.1]

Component-wise operation. Parameters specified as *angle* are assumed to be in units of radians. T is float, vec2, vec3, vec4.

T **radians**(T *degrees*)	degrees to radians
T **degrees**(T *radians*)	radians to degrees
T **sin**(T *angle*)	sine
T **cos**(T *angle*)	cosine
T **tan**(T *angle*)	tangent
T **asin**(T *x*)	arc sine
T **acos**(T *x*)	arc cosine
T **atan**(T *y*, T *x*) T **atan**(T *y_over_x*)	arc tangent

Exponential Functions [8.2]

Component-wise operation. T is float, vec2, vec3, vec4.

T **pow**(T *x*, T *y*)	x^y
T **exp**(T *x*)	e^x
T **log**(T *x*)	ln
T **exp2**(T *x*)	2^x
T **log2**(T *x*)	$\log_2$
T **sqrt**(T *x*)	square root
T **inversesqrt**(T *x*)	inverse square root

Common Functions [8.3]

Component-wise operation. T is float, vec2, vec3, vec4.

T **abs**(T *x*)	absolute value
T **sign**(T *x*)	returns -1.0, 0.0, or 1.0
T **floor**(T *x*)	nearest integer <= *x*
T **ceil**(T *x*)	nearest integer >= *x*
T **fract**(T *x*)	*x* - **floor**(*x*)
T **mod**(T *x*, T *y*) T **mod**(T *x*, float *y*)	modulus
T **min**(T *x*, T *y*) T **min**(T *x*, float *y*)	minimum value
T **max**(T *x*, T *y*) T **max**(T *x*, float *y*)	maximum value
T **clamp**(T *x*, T *minVal*, T *maxVal*) T **clamp**(T *x*, float *minVal*, float *maxVal*)	**min**(**max**(*x*, **minVal**), **maxVal**)
T **mix**(T *x*, T *y*, T *a*) T **mix**(T *x*, T *y*, float *a*)	linear blend of *x* and *y*
T **step**(T *edge*, T *x*) T **step**(float *edge*, T *x*)	0.0 if *x* < *edge*, else 1.0
T **smoothstep**(T *edge0*, T *edge1*, T *x*) T **smoothstep**(float *edge0*, float *edge1*, T *x*)	clip and smooth

Geometric Functions [8.4]

These functions operate on vectors as vectors, not component-wise. T is float, vec2, vec3, vec4.

float **length**(T *x*)	length of vector
float **distance**(T *p0*, T *p1*)	distance between points
float **dot**(T *x*, T *y*)	dot product
vec3 **cross**(vec3 *x*, vec3 *y*)	cross product
T **normalize**(T *x*)	normalize vector to length 1
T **faceforward**(T *N*, T *I*, T *Nref*)	returns *N* if **dot**(*Nref*, *I*) < 0, else -*N*
T **reflect**(T *I*, T *N*)	reflection direction *I* - 2 * **dot**(*N*,*I*) * *N*
T **refract**(T *I*, T *N*, float *eta*)	refraction vector

Matrix Functions [8.5]

Type mat is any matrix type.

mat **matrixCompMult**(mat *x*, mat *y*)	multiply *x* by *y* component-wise

Vector Relational Functions [8.6]

Compare *x* and *y* component-wise. Sizes of input and return vectors for a particular call must match. Type bvec is bvec*n*; vec is vec*n*; ivec is ivec*n* (where *n* is 2, 3, or 4). T is the union of vec and ivec.

bvec **lessThan**(T *x*, T *y*)	x < y
bvec **lessThanEqual**(T *x*, T *y*)	x <= y
bvec **greaterThan**(T *x*, T *y*)	x > y
bvec **greaterThanEqual**(T *x*, T *y*)	x >= y
bvec **equal**(T *x*, T *y*) bvec **equal**(bvec *x*, bvec *y*)	x == y
bvec **notEqual**(T *x*, T *y*) bvec **notEqual**(bvec *x*, bvec *y*)	x!= y
bool **any**(bvec *x*)	true if any component of *x* is true
bool **all**(bvec *x*)	true if all components of *x* are true
bvec **not**(bvec *x*)	logical complement of *x*

Texture Lookup Functions [8.7]

Available only in vertex shaders.

vec4 **texture2DLod**(sampler2D *sampler*, vec2 *coord*, float *lod*)
vec4 **texture2DProjLod**(sampler2D *sampler*, vec3 *coord*, float *lod*)
vec4 **texture2DProjLod**(sampler2D *sampler*, vec4 *coord*, float *lod*)
vec4 **textureCubeLod**(samplerCube *sampler*, vec3 *coord*, float *lod*)

Available only in fragment shaders.

vec4 **texture2D**(sampler2D *sampler*, vec2 *coord*, float *bias*)
vec4 **texture2DProj**(sampler2D *sampler*, vec3 *coord*, float *bias*)
vec4 **texture2DProj**(sampler2D *sampler*, vec4 *coord*, float *bias*)
vec4 **textureCube**(samplerCube *sampler*, vec3 *coord*, float *bias*)

Available in vertex and fragment shaders.

vec4 **texture2D**(sampler2D *sampler*, vec2 *coord*)
vec4 **texture2DProj**(sampler2D *sampler*, vec3 *coord*)
vec4 **texture2DProj**(sampler2D *sampler*, vec4 *coord*)
vec4 **textureCube**(samplerCube *sampler*, vec3 *coord*)

Statements and Structure

Iteration and Jumps [6]

Function Call	call by value-return

Iteration	for (;;) { break, continue }
	while ( ) { break, continue }
	do { break, continue } while ( );

Selection	if ( ) { } if ( ) { } else { }
Jump	break, continue, return discard // Fragment shader only
Entry	void main()

Sample Program

A shader pair that applies diffuse and ambient lighting to a textured object.

Vertex Shader

```
uniform   mat4  mvp_matrix;     // model-view-projection matrix
uniform   mat3  normal_matrix;  // normal matrix
uniform   vec3  ec_light_dir;   // light direction in eye coords

attribute vec4  a_vertex;       // vertex position
attribute vec3  a_normal;       // vertex normal
attribute vec2  a_texcoord;     // texture coordinates

varying   float v_diffuse;
varying   vec2  v_texcoord;

void main(void)
{
  // put vertex normal into eye coords
  vec3  ec_normal  = normalize(normal_matrix * a_normal);

  // emit diffuse scale factor, texcoord, and position
  v_diffuse        = max(dot(ec_light_dir, ec_normal), 0.0);
  v_texcoord       = a_texcoord;
  gl_Position      = mvp_matrix * a_vertex;
}
```

Fragment Shader

```
precision  mediump  float;

uniform    sampler2D  t_reflectance;
uniform    vec4       i_ambient;

varying    float      v_diffuse;
varying    vec2       v_texcoord;

void main (void)
{
  vec4   color  = texture2D(t_reflectance, v_texcoord);
  gl_FragColor  = color * (vec4(v_diffuse) + i_ambient);
}
```