OpenGL ES 3.0 API Reference Card

OpenGL® ES is a software interface to graphics hardware. The interface consists of a set of procedures and functions that allow a programmer to specify the objects and operations involved in producing high-quality graphical images, specifically color images of three-dimensional objects.

- **[n.n.n]** refers to sections and tables in the OpenGL ES 3.0 specification.
- **[n.n.n]** refers to sections in the OpenGL ES Shading Language 3.0 specification.

Specifications are available at www.khronos.org/registry/gles/

Errors [2.5]

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

NO_ERROR	No error encountered
INVALID_ENUM	Enum argument out of range
INVALID_VALUE	Numeric argument out of range
INVALID_OPERATION	Operation illegal in current state
INVALID_FRAMEBUFFER_OPERATION	Framebuffer is incomplete
OUT_OF_MEMORY	Not enough memory left to execute command

OpenGL ES Command Syntax [2.3]

Open GL ES commands are formed from a return type, a name, and optionally a type letter: i for 32-bit int, i64 for int64, f for 32-bit float, or ui for 32-bit uint, as shown by the prototype below:

return-type **Name**{1234}{i i64 f ui}{v} (*[args ,] T arg1 , . . . , T argN [, args]*);

The arguments enclosed in brackets (*[args ,]* and *[, args]*) may or may not be present.
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. If "v" is present, an array of *N* items is passed by a pointer.

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

GL Data Types [2.3]

GL types are not C types.

GL Type	Minimum Bit Width	Description
boolean	1	Boolean
byte	8	Signed 2's complement 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
int64	64	Signed 2's complement binary integer
uint64	64	Unsigned binary integer
fixed	32	Signed 2's complement 16.16 scaled 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
sync	*ptrbits*	Sync object handle
bitfield	32	Bit field
half	16	Half-precision float encoded in unsigned scalar
float	32	Floating-point value
clampf	32	Floating-point value clamped to [0, 1]

Buffer Objects [2.9]

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

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

void **DeleteBuffers**(sizei *n*, const uint **buffers*);

Creating and Binding Buffer Objects

void **BindBuffer**(enum *target*, uint *buffer*);
target: {ELEMENT_}ARRAY_BUFFER, PIXEL_{UN}PACK_BUFFER, COPY_{READ, WRITE}_BUFFER, UNIFORM_BUFFER, TRANSFORM_FEEDBACK_BUFFER

void **BindBufferRange**(enum *target*, uint *index*, uint *buffer*, intptr *offset*, sizeiptr *size*);
target: TRANSFORM_FEEDBACK_BUFFER, UNIFORM_BUFFER

void **BindBufferBase**(enum *target*, uint *index*, uint *buffer*);
target: TRANSFORM_FEEDBACK_BUFFER, UNIFORM_BUFFER

Creating Buffer Object Data Stores

void **BufferData**(enum *target*, sizeiptr *size*, const void **data*, enum *usage*);
target: See ***BindBuffer***
usage: {STATIC, STREAM, DYNAMIC}_{DRAW, READ, COPY}

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

Mapping and Unmapping Buffer Data

void ***MapBufferRange**(enum *target*, intptr *offset*, sizeiptr *length*, bitfield *access*);
target: See ***BindBuffer***
access: Bitwise OR of MAP_{READ, WRITE}_BIT, MAP_INVALIDATE_{RANGE, BUFFER_BIT}, MAP_FLUSH_EXPLICIT_BIT, MAP_UNSYNCHRONIZED_BIT

void **FlushMappedBufferRange**(enum *target*, intptr *offset*, sizeiptr *length*);
target: See ***BindBuffer***

boolean **UnmapBuffer**(enum *target*);
target: See ***BindBuffer***

Copying Between Buffers

void **CopyBufferSubData**(enum *readtarget*, enum *writetarget*, intptr *readoffset*, intptr *writeoffset*, sizeiptr *size*);
readtarget, writetarget: See *target* for ***BindBuffer***

Buffer Object Queries [6.1.9]

boolean **IsBuffer**(uint *buffer*);

void **GetBufferParameteriv**(enum *target*, enum *pname*, int * *data*);
target: See ***BindBuffer***
pname: BUFFER_{SIZE, USAGE, ACCESS_FLAGS, MAPPED}, BUFFER_ MAP_{POINTER, OFFSET, LENGTH}

void **GetBufferParameteri64v**(enum *target*, enum *pname*, int64 **data*);
target, pname: See ***GetBufferParameteriv***

void **GetBufferPointerv**(enum *target*, enum *pname*, void ***params*);
target: See ***BindBuffer***
pname: BUFFER_ MAP_POINTER

Vertex Array Objects [2.10, 6.1.10]

void **GenVertexArrays**(sizei *n*, uint **arrays*);

void **DeleteVertexArrays**(sizei *n*, const uint **arrays*);

void **BindVertexArray**(uint *array*);

boolean **IsVertexArray**(uint *array*);

Asynchronous Queries [2.13, 6.1.7]

void **GenQueries**(sizei *n*, uint **ids*);

void **BeginQuery**(enum *target*, uint *id*);
target: ANY_SAMPLES_PASSED{_CONSERVATIVE}

void **EndQuery**(enum *target*);
target: ANY_SAMPLES_PASSED{_CONSERVATIVE}

void **DeleteQueries**(sizei *n*, const uint **ids*);

boolean **IsQuery**(uint *id*);

void **GetQueryiv**(enum *target*, enum *pname*, int **params*);

void **GetQueryObjectuiv**(uint *id*, enum *pname*, uint **params*);

Transform Feedback [2.14, 6.1.11]

void **GenTransformFeedbacks**(sizei *n*, uint **ids*);

void **DeleteTransformFeedbacks**(sizei *n*, const uint **ids*);

void **BindTransformFeedback**(enum *target*, uint *id*);
target: TRANSFORM_FEEDBACK

void **BeginTransformFeedback**(enum *primitiveMode*);
primitiveMode: TRIANGLES, LINES, POINTS

void **EndTransformFeedback**(void);

void **PauseTransformFeedback**(void);

void **ResumeTransformFeedback**(void);

boolean **IsTransformFeedback**(uint *id*);

Reading and Copying Pixels [4.3.1-2]

void **ReadPixels**(int *x*, int *y*, sizei *width*, sizei *height*, enum *format*, enum *type*, void **data*);
format: RGBA, RGBA_INTEGER
type: INT, UNSIGNED_INT_2_10_10_10_REV, UNSIGNED_{BYTE, INT}
Note: **ReadPixels()** also accepts a queriable implementation-chosen *format/type* combination [4.3.1].

void **ReadBuffer**(enum *src*);
src: BACK, NONE, or COLOR_ATTACHMENT*i* where *i* may range from zero to the value of MAX_COLOR_ATTACHMENTS - 1

void **BlitFramebuffer**(int *srcX0*, int *srcY0*, int *srcX1*, int *srcY1*, int *dstX0*, int *dstY0*, int *dstX1*, int *dstY1*, bitfield *mask*, enum *filter*);
mask: Bitwise OR of {COLOR, DEPTH, STENCIL}_BUFFER_BIT
filter: LINEAR or NEAREST

Rasterization [3]

Points [3.4]

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

Line Segments [3.5]

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

Polygons [3.6]

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);

Viewport and Clipping [2.12.1]

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

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

Vertices

Current Vertex State [2.7]

void **VertexAttrib{1234}f**(uint *index*, float *values*);

void **VertexAttrib{1234}fv**(uint *index*, const float **values*);

void **VertexAttribI4{i ui}**(uint *index*, T *values*);

void **VertexAttribI4{i ui}v**(uint *index*, const T *values*);

Vertex Arrays [2.8]

Vertex data may be sourced from arrays stored in client's address space (via a pointer) or in server's address space (in a buffer object).

void **VertexAttribPointer**(uint *index*, int *size*, enum *type*, boolean *normalized*, sizei *stride*, const void **pointer*);
type: {UNSIGNED_}BYTE, {UNSIGNED_}SHORT, {UNSIGNED_}INT, FIXED, {HALF_}FLOAT, {UNSIGNED_}INT_2_10_10_10_REV
index: [0, MAX_VERTEX_ATTRIBS - 1]

void **VertexAttribIPointer**(uint *index*, int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: {UNSIGNED_}BYTE, {UNSIGNED_}SHORT, {UNSIGNED_}INT
index: [0, MAX_VERTEX_ATTRIBS - 1]

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

void **DisableVertexAttribArray**(uint *index*);

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

void **Enable**(enum *target*);

void **Disable**(enum *target*);
target: PRIMITIVE_RESTART_FIXED_INDEX

Drawing [2.8.3]

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

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

void **DrawElements**(enum *mode*, sizei *count*, enum *type*, const void **indices*);
type: UNSIGNED_BYTE, UNSIGNED_SHORT, UNSIGNED_INT

void **DrawElementsInstanced**(enum *mode*, sizei *count*, enum *type*, const void **indices*, sizei *primcount*);
type: UNSIGNED_BYTE, UNSIGNED_SHORT, UNSIGNED_INT

void **DrawRangeElements**(enum *mode*, uint *start*, uint *end*, sizei *count*, enum *type*, const void **indices*);
mode: POINTS, TRIANGLES, LINES, LINE_{STRIP, LOOP}, TRIANGLE_STRIP, TRIANGLE_FAN
type: UNSIGNED_BYTE, UNSIGNED_SHORT, UNSIGNED_INT

Shaders and Programs

Shader Objects [2.11.1]

uint **CreateShader**(enum *type*);
type: VERTEX_SHADER, FRAGMENT_SHADER

void **ShaderSource**(uint *shader*, sizei *count*, const char * const *string, const int *length);

void **CompileShader**(uint *shader*);

void **ReleaseShaderCompiler**(void);

void **DeleteShader**(uint *shader*);

Loading Shader Binaries [2.11.2]

void **ShaderBinary**(sizei *count*, const uint *shaders, enum *binaryformat*, const void *binary, sizei *length*);

Program Objects [2.11.3-4]

uint **CreateProgram**(void);

void **AttachShader**(uint *program*, uint *shader*);

void **DetachShader**(uint *program*, uint *shader*);

void **LinkProgram**(uint *program*);

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

void **ProgramParameteri**(uint *program,* enum *pname,* int *value*);
pname: PROGRAM_BINARY_RETRIEVABLE_HINT

void **DeleteProgram**(uint *program*);

void **GetProgramBinary**(uint *program*, sizei *bufSize*, sizei *length, enum *binaryFormat, void *binary);

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

Vertex Attributes [2.11.5]

void **GetActiveAttrib**(uint *program*, uint *index*, sizei *bufSize*, sizei *length, int *size, enum *type, char *name);
**type* returns: FLOAT, FLOAT_VEC{2,3,4}, FLOAT_MAT{2,3,4}, FLOAT_MAT{2x3, 2x4, 3x2, 3x4, 4x2, 4x3}, {UNSIGNED_}INT, {UNSIGNED_}INT_VEC{2,3,4}

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

void **BindAttribLocation**(uint *program*, uint *index*, const char *name);

Uniform Variables [2.11.6]

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

uint **GetUniformBlockIndex**(uint *program*, const char *uniformBlockName);

void **GetActiveUniformBlockName**(uint *program*, uint *uniformBlockIndex*, sizei *bufSize*, sizei *length, char *uniformBlockName);

void **GetActiveUniformBlockiv**(uint *program*, uint *uniformBlockIndex*, enum *pname*, int *params);
pname: UNIFORM_BLOCK_{BINDING, DATA_SIZE, NAME_LENGTH}, UNIFORM_BLOCK_ACTIVE_{UNIFORMS,UNIFORM_INDICES}, UNIFORM_BLOCK_REFERENCED_BY_{VERTEX,FRAGMENT}_SHADER

void **GetUniformIndices**(uint *program*, sizei *uniformCount*, const char * const *uniformNames, uint *uniformIndices);

void **GetActiveUniform**(uint *program*, uint *uniformIndex*, sizei *bufSize*, sizei *length, int *size, enum *type, char *name);
**type* returns: FLOAT, BOOL, {FLOAT, BOOL}_VEC{2, 3, 4}, {UNSIGNED_}INT, {UNSIGNED_}INT_VEC{2, 3, 4}, FLOAT_MAT{2, 3, 4}, FLOAT_MAT{2x3, 2x4, 3x2, 3x4, 4x2, 4x3}, SAMPLER_{2D, 3D}, SAMPLER_ {CUBE_SHADOW}, SAMPLER_2D{_ARRAY}_SHADOW, {UNSIGNED_}INT_SAMPLER_{2D, 3D, CUBE}, {{UNSIGNED_}INT_}SAMPLER_2D_ARRAY

void **GetActiveUniformsiv**(uint *program*, sizei *uniformCount*, const uint *uniformIndices, enum *pname*, int *params);
pname: UNIFORM_TYPE, UNIFORM_SIZE, UNIFORM_NAME_LENGTH, UNIFORM_BLOCK_INDEX, UNIFORM_{OFFSET, ARRAY_STRIDE}, UNIFORM_MATRIX_STRIDE, UNIFORM_IS_ROW_MAJOR

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

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

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

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

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

void **UniformMatrix{2x3,3x2,2x4,4x2,3x4,4x3}fv**(int *location*, sizei *count*, boolean *transpose*, const float *value*);

void **UniformBlockBinding**(uint *program*, uint *uniformBlockIndex*, uint *uniformBlockBinding*);

Output Variables [2.11.8]

void **TransformFeedbackVaryings**(uint *program*, sizei *count*, const char * const *varyings, enum *bufferMode*);
bufferMode: INTERLEAVED_ATTRIBS, SEPARATE_ATTRIBS

void **GetTransformFeedbackVarying**(uint *program*, uint *index*, sizei *bufSize*, sizei *length, sizei *size, enum *type, char *name);
**type* returns any of the scalar, vector, or matrix attribute types returned by GetActiveAttrib().

Shader Execution [2.11.9, 3.9.2]

void **ValidateProgram**(uint *program*);

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

Shader Queries

Shader Queries [6.1.12]

boolean **IsShader**(uint *shader*);

void **GetShaderiv**(uint *shader*, enum *pname*, int *params);
pname: SHADER_TYPE, {VERTEX, FRAGMENT_SHADER}, {DELETE, COMPILE}_STATUS, INFO_LOG_LENGTH, SHADER_SOURCE_LENGTH

void **GetAttachedShaders**(uint *program*, sizei *maxCount*, sizei *count, uint *shaders);

void **GetShaderInfoLog**(uint *shader*, sizei *bufSize*, sizei *length, char *infoLog);

void **GetShaderSource**(uint *shader*, sizei *bufSize*, sizei *length, char *source);

void **GetShaderPrecisionFormat**(enum *shadertype*, enum *precisiontype*, int *range, int *precision);
shadertype: VERTEX_SHADER, FRAGMENT_SHADER
precision: LOW_FLOAT, MEDIUM_FLOAT, HIGH_FLOAT, LOW_INT, MEDIUM_INT, HIGH_INT

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

void **GetVertexAttribiv**(uint *index*, enum *pname*, int *params);
pname: See ***GetVertexAttribfv()***

void **GetVertexAttribIiv**(uint *index*, enum *pname*, int *params);
pname: See ***GetVertexAttribfv()***

void **GetVertexAttribIuiv**(uint *index*, enum *pname*, uint *params);
pname: See ***GetVertexAttribfv()***

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

void **GetUniformfv**(uint *program*, int *location*, float *params);

void **GetUniformiv**(uint *program*, int *location*, int *params);

void **GetUniformuiv**(uint *program*, int *location*, uint *params);

Program Queries [6.1.12]

boolean **IsProgram**(uint *program*);

void **GetProgramiv**(uint *program*, enum *pname*, int *params);
pname: {DELETE, LINK, VALIDATE}_STATUS, INFO_LOG_LENGTH, TRANSFORM_FEEDBACK_VARYINGS, TRANSFORM_{FEEDBACK_BUFFER_MODE, VARYINGS}, TRANSFORM_FEEDBACK_VARYING_MAX_LENGTH, ATTACHED_SHADERS, ACTIVE_{ATTRIBUTES, UNIFORMS}, ACTIVE_{ATTRIBUTE, UNIFORM}_MAX_LENGTH, ACTIVE_UNIFORM_BLOCK_MAX_NAME_LENGTH, PROGRAM_BINARY_RETRIEVABLE_HINT, ACTIVE_UNIFORM_BLOCKS

void **GetProgramInfoLog**(uint *program*, sizei *bufSize*, sizei *length, char *infoLog);

Texturing [3.8]

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: [TEXTURE0..TEXTURE*i*] where *i* = [MAX_COMBINED_TEXTURE_IMAGE_UNITS-1]

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

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

void **DeleteTextures**(sizei *n*, const uint *textures);

Sampler Objects [3.8.2]

void **GenSamplers**(sizei *count*, uint *samplers);

void **BindSampler**(uint *unit*, uint *sampler*);

void **SamplerParameter{if}**(uint *sampler*, enum *pname*, T *param*);
pname: TEXTURE_WRAP_{S, T, R}, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_{MIN, MAX}_LOD, TEXTURE_COMPARE_{MODE, FUNC}

void **SamplerParameter{if}v**(uint *sampler*, enum *pname*, const T *params);
pname: See ***SamplerParameter{if}***

void **DeleteSamplers**(sizei *count*, const uint *samplers);

Sampler Queries [6.1.5]

boolean **IsSampler**(uint *sampler*);

void **GetSamplerParameter{if}v**(uint *sampler*, enum *pname*, T *params);
pname: See ***SamplerParameter{if}***

Texture Image Specification [3.8.3, 3.8.4]

void **TexImage3D**(enum *target*, int *level*, int *internalformat*, sizei *width*, sizei *height*, sizei *depth*, int *border*, enum *format*, enum *type*, const void *data);
target: TEXTURE_3D, TEXTURE_2D_ARRAY
format: ALPHA, RGBA, RGB, RG, RED, {RGBA, RGB, RG, RED}_INTEGER, DEPTH_{COMPONENT, STENCIL}, LUMINANCE_ALPHA, LUMINANCE

(more parameters ↗)

type: {UNSIGNED_}BYTE, {UNSIGNED_}SHORT, {UNSIGNED_}INT, {HALF_}FLOAT, UNSIGNED_SHORT_4_4_4_4, UNSIGNED_SHORT_5_5_5_1, UNSIGNED_SHORT_5_6_5, UNSIGNED_INT_2_10_10_10_REV, UNSIGNED_INT_24_8, UNSIGNED_INT_10F_11F_11F_REV, UNSIGNED_INT_5_9_9_9_REV, FLOAT_32_UNSIGNED_INT_24_8_REV
internalformat: R8, R8I, R8UI, R8_SNORM, R16I, R16UI, R16F, R32I, R32UI, R32F, RG8, RG8I, RG8UI, RG8_SNORM, RG16I, RG16UI, RG16F, RG32I, RG32UI, RG32F, RGB, RGB5_A1, RGB565, RGB8, RGB8I, RGB8UI, RGB8_SNORM, RGB9_E5, RGB10_A2, RGB10_A2UI, RGB16I, RGB16UI, RGB16F, RGB32I, RGB32UI, RGB32F, SRGB8, RGBA, RGBA4, RGBA8, RGBA8I, RGBA8UI, RGBA8_SNORM, RGBA16I, RGBA16UI, RGBA16F, RGBA32I, RGBA32UI, RGBA32F, SRGB8_ALPHA8, R11F_G11F_B10F, DEPTH_COMPONENT16,DEPTH_COMPONENT24, DEPTH_COMPONENT32F, DEPTH24_STENCIL8, DEPTH32F_STENCIL8, LUMINANCE_ALPHA, LUMINANCE, ALPHA

void **TexImage2D**(enum *target*, int *level*, int *internalformat*, sizei *width*, sizei *height*, int *border*, enum *format*, enum *type*, void *data);
target: TEXTURE_2D, TEXTURE_CUBE_MAP_{POSITIVE, NEGATIVE}_{X, Y, Z}
internalformat: See ***TexImage3D***
format, type: See ***TexImage3D***

void **TexStorage2D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*, sizei *height*);
target: TEXTURE_CUBE_MAP, TEXTURE_2D
internalformat: See ***TexImage3D*** except for unsized base internal formats in [Table 3.3]

void **TexStorage3D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*, sizei *height*, sizei *depth*);
target: TEXTURE_3D, TEXTURE_2D_ARRAY
internalformat: See ***TexImage3D*** except for unsized base internal formats in [Table 3.3]

Alt. Texture Image Specification Commands [3.8.5]

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 **CopyTexImage2D**(enum *target*, int *level*, enum *internalformat*, int *x*, int *y*, sizei *width*, sizei *height*, int *border*);
target: TEXTURE_2D, TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}
internalformat: See ***TexImage3D,*** except for DEPTH* values

void **TexSubImage3D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, int *zoffset*, sizei *width*, sizei *height*, sizei *depth*, enum *format*, enum *type*, const void *data);
target: TEXTURE_3D, TEXTURE_2D_ARRAY
format, type: See ***TexImage3D***

void **TexSubImage2D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, sizei *width*, sizei *height*, enum *format*, enum *type*, const void *data);
target: TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_2D, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}
format, type: See ***TexImage3D***

void **CopyTexSubImage3D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, int *zoffset*, int *x*, int *y*, sizei *width*, sizei *height*);
target: TEXTURE_3D, TEXTURE_2D_ARRAY

(Continued on next page >)

Texturing (continued)

void **CopyTexSubImage2D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, int *x*, int *y*, sizei *width*, sizei *height*);
target: TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_2D, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}

Compressed Texture Images [3.8.6]

void **CompressedTexImage2D**(enum *target*, int *level*, enum *internalformat*, sizei *width*, sizei *height*, int *border*, sizei *imageSize*, const void **data*);
target: See *TexImage2D*
internalformat: COMPRESSED_RGBA8_ETC2_EAC, COMPRESSED_{R11, SIGNED_R11, RG11, SIGNED_RG11}_EAC, COMPRESSED_{S}RGB8{_PUNCHTHROUGH_ALPHA1}_ETC2, COMPRESSED_SRGB8_ALPHA8_ETC2_EAC [Table 3.16]

void **CompressedTexImage3D**(enum *target*, int *level*, enum *internalformat*, sizei *width*, sizei *height*, sizei *depth*, int *border*, sizei *imageSize*, const void **data*);
target: see *TexImage3D*
internalformat: See *TexImage2D*

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

void **CompressedTexSubImage3D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, int *zoffset*, sizei *width*, sizei *height*, sizei *depth*, enum *format*, sizei *imageSize*, const void **data*);
target: See *TexSubImage2D*

Texture Parameters [3.8.7]

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

void **TexParameter{if}v**(enum *target*, enum *pname*, const T **params*);
target: TEXTURE_{2D, 3D}, TEXTURE_2D_ARRAY, TEXTURE_CUBE_MAP
pname: TEXTURE_{BASE, MAX}_LEVEL, TEXTURE_{MIN, MAX}_LOD, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_COMPARE_{MODE,FUNC}, TEXTURE_SWIZZLE_{R,G,B,A}, TEXTURE_WRAP_{S,T,R}

Manual Mipmap Generation [3.8.9]

void **GenerateMipmap**(enum *target*);
target: TEXTURE_{2D,3D}, TEXTURE_{2D_ARRAY, CUBE_MAP}

Enumerated Queries [6.1.3]

void **GetTexParameter{if}v**(enum *target*, enum *value*, T *data*);
target: TEXTURE_{2D, 3D}, TEXTURE_{2D_ARRAY, CUBE_MAP}
value: TEXTURE_{BASE, MAX}_LEVEL, TEXTURE_{MIN, MAX}_LOD, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_IMMUTABLE_FORMAT, TEXTURE_COMPARE_{FUNC, MODE}, TEXTURE_WRAP_{S, T, R}, TEXTURE_SWIZZLE_{R, G, B, A}

Texture Queries [6.1.4]

boolean **IsTexture**(uint *texture*);

Framebuffer Objects

Binding & Managing Framebuffer Objects [4.4.1]

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

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

void **DeleteFramebuffers**(sizei *n*, const uint **framebuffers*);

Renderbuffer Objects [4.4.2]

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

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

void **DeleteRenderbuffers**(sizei *n*, const uint **renderbuffers*);

void **RenderbufferStorageMultisample**(enum *target*, sizei *samples*, enum *internalformat*, sizei *width*, sizei *height*);
target: RENDERBUFFER
internalformat: {R,RG,RGB}8, RGB{565, A4, 5_A1, 10_A2}, RGB{10_A2UI}, R{8,16,32}I, RG{8,16,32}I, R{8,16,32}UI, RG{8,16,32}UI, RGBA, RGBA{8, 8I, 8UI, 16I, 16UI, 32I, 32UI}, SRGB8_ALPHA8, STENCIL_INDEX8, DEPTH{24, 32F}_STENCIL8, DEPTH_COMPONENT{16, 24, 32F}

void **RenderbufferStorage**(enum *target*, enum *internalformat*, sizei *width*, sizei *height*);
target: RENDERBUFFER
internalformat: See *RenderbufferStorageMultisample*

Attaching Renderbuffer Images to Framebuffer

void **FramebufferRenderbuffer**(enum *target*, enum *attachment*, enum *renderbuffertarget*, uint *renderbuffer*);
target: FRAMEBUFFER, {DRAW, READ}_FRAMEBUFFER
attachment: DEPTH_ATTACHMENT, {DEPTH_}STENCIL_ATTACHMENT, COLOR_ATTACHMENT*i* (*i* = [0, MAX_COLOR_ATTACHMENTS-1])
renderbuffertarget: RENDERBUFFER

(parameters ↗)

Attaching Texture Images to a Framebuffer

void **FramebufferTexture2D**(enum *target*, enum *attachment*, enum *textarget*, uint *texture*, int *level*);
textarget: TEXTURE_2D, TEXTURE_CUBE_MAP_POSITIVE{X, Y, Z}, TEXTURE_CUBE_MAP_NEGATIVE{X, Y, Z}
target: FRAMEBUFFER, {DRAW, READ}_FRAMEBUFFER
attachment: See *FrameBufferRenderbuffer*

void **FramebufferTextureLayer**(enum *target*, enum *attachment*, uint *texture*, int *level*, int *layer*);
target: TEXTURE_2D_ARRAY, TEXTURE_3D
attachment: See *FrameBufferRenderbuffer*

Framebuffer Completeness [4.4.4]

enum **CheckFramebufferStatus**(enum *target*);
target: FRAMEBUFFER, {DRAW, READ}_FRAMEBUFFER
returns: FRAMEBUFFER_COMPLETE or a constant indicating which value violates framebuffer completeness

Invalidating Framebuffer Contents [4.5]

void **InvalidateSubFramebuffer**(enum *target*, sizei *numAttachments*, const enum **attachments*, int *x*, int *y*, sizei *width*, sizei *height*);
target: FRAMEBUFFER
attachments: points to an array of COLOR, STENCIL, {DEPTH, STENCIL}_ATTACHMENT, COLOR_ATTACHMENT*i*

void **InvalidateFramebuffer**(enum *target*, sizei *numAttachments*, const enum **attachments*);

Renderbuffer Object Queries [6.1.14]

boolean **IsRenderbuffer**(uint *renderbuffer*);

void **GetRenderbufferParameteriv**(enum *target*, enum *pname*, int **params*);
target: RENDERBUFFER
pname: RENDERBUFFER_*x*, where *x* may be WIDTH, HEIGHT, {RED, GREEN, BLUE}_SIZE, {ALPHA, DEPTH, STENCIL}_SIZE, SAMPLES, INTERNAL_FORMAT

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*);
func: NEVER, ALWAYS, LESS, GREATER, {L, G}EQUAL, {NOT}EQUAL

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

void **StencilOp**(enum *sfail*, enum *dpfail*, enum *dppass*);
sfail, dpfail, and *dppass:* KEEP, ZERO, REPLACE, INCR, DECR, INVERT, INCR_WRAP, DECR_WRAP

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, GREATER, {L, G}EQUAL, {NOT}EQUAL

Depth Buffer Test [4.1.5]

Enable/Disable(DEPTH_TEST);

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

Blending [4.1.7]

Enable/Disable(BLEND); *(applies to all draw buffers)*

void **BlendEquation**(enum *mode*);

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

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

void **BlendFunc**(enum *src*, enum *dst*);
src, dst: See *BlendFuncSeparate*

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

Dithering [4.1.9]

Enable/Disable(DITHER);

Whole Framebuffer Operations

Selecting a Buffer for Writing [4.2.1]

void **DrawBuffers**(sizei *n*, const enum **bufs*);
bufs points to an array of *n* BACK, NONE, or COLOR_ATTACHMENT*i* where *i* = [0,MAX_COLOR_ATTACHMENTS - 1].

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*);

void **ClearBuffer{if ui}v**(enum *buffer*, int *drawbuffer*, const T **value*);
buffer: COLOR, DEPTH, STENCIL

void **ClearBufferfi**(enum *buffer*, int *drawbuffer*, float *depth*, int *stencil*);
buffer: DEPTH_STENCIL
drawbuffer: 0

Pixel Rectangles [3.7.1]

void **PixelStorei**(enum *pname*, T *param*);
pname: {UN}PACK_ROW_LENGTH, {UN}PACK_ALIGNMENT, {UN}PACK_SKIP_{ROWS,PIXELS}, {UN}PACK_IMAGE_HEIGHT, {UN}PACK_SKIP_IMAGES

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);

Sync Objects and Fences [5.2]

sync **FenceSync**(enum *condition*, bitfield *flags*);
condition: SYNC_GPU_COMMANDS_COMPLETE
flags: 0

void **DeleteSync**(sync *sync*);

enum **ClientWaitSync**(sync *sync*, bitfield *flags*, uint64 *timeout*);
flags: 0 or SYNC_FLUSH_COMMANDS_BIT
timeout: nanoseconds

void **WaitSync**(sync *sync*, bitfield *flags*, uint64 *timeout*);
flags: 0
timeout: TIMEOUT_IGNORED

Hints [5.3]

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

Sync Object Queries [6.1.8]

sync **GetSynciv**(sync *sync*, enum *pname*, sizei *bufSize*, sizei **length*, int **values*);
pname: OBJECT_TYPE, SYNC_{STATUS, CONDITION, FLAGS}

boolean **IsSync**(sync *sync*);

(Continued on next page >)

Framebuffer Objects (cont'd)

Framebuffer Object Queries [6.1.13]

boolean **IsFramebuffer**(uint *framebuffer*);

void **GetFramebufferAttachmentParameteriv**(enum *target*, enum *attachment*, enum *pname*, int **params*);

target: FRAMEBUFFER, {DRAW, READ}_FRAMEBUFFER
attachment: BACK, STENCIL, COLOR_ATTACHMENT*i*, {DEPTH, STENCIL, DEPTH_STENCIL}_ATTACHMENT
pname: FRAMEBUFFER_ATTACHMENT_*x*, where *x* may be one of OBJECT_{TYPE, NAME}, COMPONENT_TYPE, COLOR_ENCODING, {RED, GREEN, BLUE, ALPHA}_SIZE, {DEPTH, STENCIL}_SIZE, TEXTURE_{LEVEL, LAYER}, TEXTURE_CUBE_MAP_FACE

(more parameters ↗)

void **GetInternalformativ**(enum *target*, enum *internalformat*, enum *pname*, sizei *bufSize*, int **params*);

internalformat: See ***RenderbufferStorageMultisample***
target: RENDERBUFFER
pname: NUM_SAMPLE_COUNTS, SAMPLES

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 *pname*, boolean **data*);

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

void **GetInteger64v**(enum *pname*, int64 **data*);

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

void **GetIntegeri_v**(enum *target*, uint *index*, int **data* ;

void **GetInteger64i_v**(enum *target*, uint *index*, int64 **data*);

boolean **IsEnabled**(enum *cap*);

String Queries [6.1.6]

ubyte ***GetString**(enum *name*);
name: VENDOR, RENDERER, EXTENSIONS, {SHADING_LANGUAGE_}VERSION

ubyte ***GetStringi**(enum *name*, uint *index*);
name: EXTENSIONS

OpenGL ES Shading Language 3.0 Reference Card

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 3.0 specification at www.khronos.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, uint	signed, unsigned integer
float	floating scalar
vec2, vec3, vec4	n-component floating point vector
bvec2, bvec3, bvec4	Boolean vector
ivec2, ivec3, ivec4	signed integer vector
uvec2, uvec3, uvec4	unsigned integer vector
mat2, mat3, mat4	2x2, 3x3, 4x4 float matrix
mat2x2, mat2x3, mat2x4	2x2, 2x3, 2x4 float matrix
mat3x2, mat3x3, mat3x4	3x2, 3x3, 3x4 float matrix
mat4x2, mat4x3, mat4x4	4x2, 4x3, 4x4 float matrix

Floating Point Sampler Types (opaque)

sampler2D, sampler3D	access a 2D or 3D texture
samplerCube	access cube mapped texture
samplerCubeShadow	access cube map depth texture with comparison
sampler2DShadow	access 2D depth texture with comparison
sampler2DArray	access 2D array texture
sampler2DArrayShadow	access 2D array depth texture with comparison

Signed Integer Sampler Types (opaque)

isampler2D, isampler3D	access an integer 2D or 3D texture
isamplerCube	access integer cube mapped texture
isampler2DArray	access integer 2D array texture

Unsigned Integer Sampler Types (opaque)

usampler2D, usampler3D	access unsigned integer 2D or 3D texture
usamplerCube	access unsigned integer cube mapped texture
usampler2DArray	access unsigned integer 2D array 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, blocks, and structure members can be arrays only 1-dimensional arrays supported

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* *#line*

Examples of Preprocessor Directives

- "#version 300 es" must appear in the first line of a shader program written in GLSL ES version 3.00. If omitted, the shader will be treated as targeting version 1.00.
- #extension *extension_name* : *behavior*, where *behavior* can be require, enable, warn, or disable; and where *extension_name is* the extension supported by the compiler
- #pragma optimize({on, off}) - enable or disable shader optimization (default on)
  #pragma debug({on, off}) - enable or disable compiling shaders with debug information (default off)

Predefined Macros

__LINE__	Decimal integer constant that is one more than the number of preceding newlines in the current source string
__FILE__	Decimal integer constant that says which source string number is currently being processed.
__VERSION__	Decimal integer, e.g.: 300
GL_ES	Defined and set to integer 1 if running on an OpenGL-ES Shading Language.

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. [8.7].

	Operator	Description	Assoc.
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
6.	<< >>	bit-wise shift	L - R
7.	< > <= >=	relational	L - R
8.	== !=	equality	L - R
9.	&	bit-wise and	L - R
10.	^	bit-wise exclusive or	L - R
11.	|	bit-wise inclusive or	L - R
12.	&&	logical and	L - R
13.	^^	logical exclusive or	L - R
14.	||	logical inclusive or	L - R
15.	? :	selection (Selects an entire operand. Use mix() to select individual components of vectors.)	L - R
16.	= += -= *= /= %= <<= >>= &= ^= |=	assignment arithmetic assignments	L - R 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

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.
in **centroid in**	linkage into a shader from a previous stage
out **centroid out**	linkage out of a shader to a subsequent stage
uniform	Value does not change across the primitive being processed, uniforms form the linkage between a shader, OpenGL ES, and the application

The following interpolation qualifiers for shader outputs and inputs may procede **in**, **centroid in**, **out**, or **centroid out**.

smooth	perspective correct interpolation
flat	no interpolation

Interface Blocks [4.3.7]

Uniform variable declarations can be grouped into named interface blocks, for example:

```
uniform Transform {
  mat4 ModelViewProjectionMatrix;
  uniform mat3 NormalMatrix;   // restatement of qualifier
  float Deformation;
}
```

Layout Qualifiers [4.3.8]

layout(*layout-qualifier*) *block-declaration*
layout(*layout-qualifier*) **in/out/uniform**
layout(*layout-qualifier*) **in/out/uniform** *declaration*

Input Layout Qualifiers [4.3.8.1]

For all shader stages:
location = *integer-constant*

Output Layout Qualifiers [4.3.8.2]

For all shader stages:
location = *integer-constant*

(Continued on next page >)

Qualifiers (continued)

Uniform Block Layout Qualifiers [4.3.8.3]

Layout qualifier identifiers for uniform blocks:

shared, packed, std140, {row, column}_major

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.
mediump	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.

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

	FP Range	FP Magnitude Range	FP Precision	Integer Range Signed	Integer Range Unsigned
highp	$(-2^{126}, 2^{127})$	0.0, $(2^{-126}, 2^{127})$	Relative 2^{-24}	$[-2^{31}, 2^{31}-1]$	$[0, 2^{32}-1]$
mediump	$(-2^{14}, 2^{14})$	$(2^{-14}, 2^{14})$	Relative 2^{-10}	$[-2^{15}, 2^{15}-1]$	$[0, 2^{16}-1]$
lowp	(−2, 2)	$(2^{-8}, 2)$	Absolute 2^{-8}	$[-2^{7}, 2^{7}-1]$	$[0, 2^{8}-1]$

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 centroid out 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 either:

invariant, interpolation, storage, precision

or:

storage, parameter, precision

Statements and Structure

Iteration and Jumps [6]

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

Selection	if ( ) { }
	if ( ) { } else { }
	switch ( ) { break, case }

Jump	break, continue, return discard // Fragment shader only
Entry	void main()

```
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. Valid operators are:

.	field selector
== !=	equality
=	assignment

Array Operations [5.7]

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

diffuseColor += lightIntensity[3] * NdotL;

The size of an array can be determined using the .**length**() operator. For example:

```
for (i = 0; i < a.length(); i++)
    a[i] = 0.0;
```

Aggregate Operations and Constructors

Matrix Constructor Examples [5.4.2]

```
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
```

(more examples ↗)

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

Shader programs use special variables to communicate with fixed-function parts of the pipeline. 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]

Inputs:

```
int     gl_VertexID;        // integer index
int     gl_InstanceID;      // instance number
```

Outputs:

```
out gl_PerVertex {
    vec4    gl_Position;    // transformed vertex position in clip coordinates
    float   gl_PointSize;   // transformed point size in pixels (point rasterization only)
};
```

Fragment Shader Special Variables [7.2]

Inputs:

```
highp vec4      gl_FragCoord;   // fragment position within frame buffer
bool            gl_FrontFacing; // fragment belongs to a front-facing primitive
mediump vec2    gl_PointCoord;  // 0.0 to 1.0 for each component
```

Outputs:

```
highp float     gl_FragDepth;   // depth range
```

Built-In Constants With Minimum Values [7.3]

Built-in Constant	Minimum value
const mediump int gl_MaxVertexAttribs	16
const mediump int gl_MaxVertexUniformVectors	256
const mediump int gl_MaxVertexOutputVectors	16
const mediump int gl_MaxFragmentInputVectors	15
const mediump int gl_MaxVertexTextureImageUnits	16
const mediump int gl_MaxCombinedTextureImageUnits	32
const mediump int gl_MaxTextureImageUnits	16
const mediump int gl_MaxFragmentUniformVectors	224
const mediump int gl_MaxDrawBuffers	4
const mediump int gl_MinProgramTexelOffset	-8
const mediump int gl_MaxProgramTexelOffset	7

Built-In Uniform State [7.4]

As an aid to accessing OpenGL ES processing state, the following uniform variables are built into the OpenGL ES Shading Language.

```
struct gl_DepthRangeParameters {
    float near;     // n
    float far;      // f
    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

(more angle & trigonometry functions ↗)

Angle & Trigonometry Functions (continued)

T **acos** (T *x*);	arc cosine
T **atan** (T *y*, T *x*); T **atan** (T *y_over_x*);	arc tangent
T **sinh** (T *x*);	hyperbolic sine
T **cosh** (T *x*);	hyperbolic cosine
T **tanh** (T *x*);	hyperbolic tangent
T **asinh** (T *x*);	arc hyperbolic sine; inverse of sinh
T **acosh** (T *x*);	arc hyperbolic cosine; non-negative inverse of cosh
T **atanh** (T *x*);	arc hyperbolic tangent; inverse of tanh

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

(Continued on next page)

Built-In Functions (continued)

Common Functions [8.3]

Component-wise operation. T is float and vec*n*, TI is int and ivec*n*, TU is uint and uvec*n*, and TB is bool and bvec*n*, where *n* is 2, 3, or 4.

T **abs**(T *x*); TI **abs**(TI *x*);	absolute value
T **sign**(T *x*); TI **sign**(TI *x*);	returns -1.0, 0.0, or 1.0
T **floor**(T *x*);	nearest integer <= *x*
T **trunc** (T *x*);	nearest integer a such that |*a*| <= |*x*|
T **round** (T *x*);	round to nearest integer
T **roundEven** (T *x*);	round to nearest integer
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*); T **modf**(T *x*, out T *i*);	modulus
T **min**(T *x*, T *y*); TI **min**(TI *x*, TI *y*); TU **min**(TU *x*, TU *y*); T **min**(T *x*, float *y*); TI **min**(TI *x*, int *y*); TU **min**(TU *x*, uint *y*);	minimum value
T **max**(T *x*, T *y*); TI **max**(TI *x*, TI *y*); TU **max**(TU *x*, TU *y*); T **max**(T *x*, float *y*); TI **max**(TI *x*, int *y*); TU **max**(TU *x*, uint *y*);	maximum value
T **clamp**(TI *x*, T *minVal*, T *maxVal*); TI **clamp**(V *x*, TI *minVal*, TI *maxVal*); TU **clamp**(TU *x*, TU *minVal*, TU *maxVal*); T **clamp**(T *x*, float *minVal*, float *maxVal*); TI **clamp**(TI *x*, int *minVal*, int *maxVal*); TU **clamp**(TU *x*, uint *minVal*, uint *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 **mix**(T *x*, T *y*, TB *a*);	Selects vector source for each returned component
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*);	clamp and smooth
TB **isnan**(T *x*);	true if *x* is a NaN
TB **isinf**(T *x*);	true if *x* is positive or negative infinity
TI **floatBitsToInt**(T *value*); TU **floatBitsToUint**(T *value*);	highp integer, preserving float bit level representation
T **intBitsToFloat**(TI *value*); T **uintBitsToFloat**(TU *value*);	highp float, preserving integer bit level representation

Floating-Point Pack and Unpack Functions [8.4]

uint **packSnorm2x16**(vec2 *v*); uint **packUnorm2x16**(vec2 *v*);	convert two floats to fixed point and pack into an integer
vec2 **unpackSnorm2x16**(uint *p*); vec2 **unpackUnorm2x16**(uint *p*);	unpack fixed point value pair into floats
uint **packHalf2x16**(vec2 *v*);	convert two floats into half-precision floats and pack into an integer
vec2 **unpackHalf2x16**(uint *v*);	unpack half value pair into full floats

Geometric Functions [8.5]

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

(more Geometric Functions ↗)

Geometric Functions (continued)

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 [8.6]

Type mat is any matrix type.

mat **matrixCompMult**(mat *x*, mat *y*);	multiply *x* by *y* component-wise
mat2 **outerProduct**(vec2 *c*, vec2 *r*); mat3 **outerProduct**(vec3 *c*, vec3 *r*); mat4 **outerProduct**(vec4 *c*, vec4 *r*);	linear algebraic column vector * row vector
mat2x3 **outerProduct**(vec3 *c*, vec2 *r*); mat3x2 **outerProduct**(vec2 *c*, vec3 *r*); mat2x4 **outerProduct**(vec4 *c*, vec2 *r*); mat4x2 **outerProduct**(vec2 *c*, vec4 *r*); mat3x4 **outerProduct**(vec4 *c*, vec3 *r*); mat4x3 **outerProduct**(vec3 *c*, vec4 *r*);	linear algebraic column vector * row vector
mat2 **transpose**(mat2 *m*); mat3 **transpose**(mat3 *m*); mat4 **transpose**(mat4 *m*); mat2x3 **transpose**(mat3x2 *m*); mat3x2 **transpose**(mat2x3 *m*); mat2x4 **transpose**(mat4x2 *m*); mat4x2 **transpose**(mat2x4 *m*); mat3x4 **transpose**(mat4x3 *m*); mat4x3 **transpose**(mat3x4 *m*);	transpose of matrix *m*
float **determinant**(mat2 *m*); float **determinant**(mat3 *m*); float **determinant**(mat4 *m*);	determinant of matrix *m*
mat2 **inverse**(mat2 *m*); mat3 **inverse**(mat3 *m*); mat4 **inverse**(mat4 *m*);	inverse of matrix *m*

Vector Relational Functions [8.7]

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

bvec **lessThan**(T *x*, T *y*); bvec **lessThan**(uvec *x*, uvec *y*);	x < y
bvec **lessThanEqual**(T *x*, T *y*); bvec **lessThanEqual**(uvec *x*, uvec *y*);	x <= y
bvec **greaterThan**(T *x*, T *y*); bvec **greaterThan**(uvec *x*, uvec *y*);	x > y
bvec **greaterThanEqual**(T *x*, T *y*); bvec **greaterThanEqual**(uvec *x*, uvec *y*);	x >= y
bvec **equal**(T *x*, T *y*); bvec **equal**(bvec *x*, bvec *y*); bvec **equal**(uvec *x*, uvec *y*);	x == y
bvec **notEqual**(T *x*, T *y*); bvec **notEqual**(bvec *x*, bvec *y*); bvec **notEqual**(uvec *x*, uvec *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 [8.8]

The function textureSize returns the dimensions of level *lod* for the texture bound to sampler, as described in [2.11.9] of the OpenGL ES 3.0 specification, under "Texture Size Query". The initial "g" in a type name is a placeholder for nothing, "i", or "u".

highp ivec{2,3}	**textureSize**(gsampler{2,3}D *sampler*, int *lod*);
highp ivec2	**textureSize**(gsamplerCube *sampler*, int *lod*);
highp ivec2	**textureSize**(sampler2DShadow *sampler*, int *lod*);
highp ivec2	**textureSize**(samplerCubeShadow *sampler*, int *lod*);
highp ivec3	**textureSize**(gsampler2DArray *sampler*, int *lod*);
highp ivec3	**textureSize**(sampler2DArrayShadow *sampler*, int *lod*);

Texture lookup functions using samplers are available to vertex and fragment shaders. The initial "g" in a type name is a placeholder for nothing, "i", or "u".

gvec4	**texture**(gsampler{2,3}D *sampler*, vec{2,3} *P* [, float *bias*]);
gvec4	**texture**(gsamplerCube *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(sampler2DShadow *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(samplerCubeShadow *sampler*, vec4 *P* [, float *bias*]);
gvec4	**texture**(gsampler2DArray *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(sampler2DArrayShadow *sampler*, vec4 *P*);

(more Texture Lookup functions ↗)

Texture Lookup Functions (continued)

gvec4	**textureProj**(gsampler2D *sampler*, vec{3,4} *P* [, float *bias*]);
gvec4	**textureProj**(gsampler3D *sampler*, vec4 *P* [, float *bias*]);
float	**textureProj**(sampler2DShadow *sampler*, vec4 *P* [, float *bias*]);
gvec4	**textureLod**(gsampler{2,3}D *sampler*, vec{2,3} *P*, float *lod*);
gvec4	**textureLod**(gsamplerCube *sampler*, vec3 *P*, float *lod*);
float	**textureLod**(sampler2DShadow *sampler*, vec3 *P*, float *lod*);
gvec4	**textureLod**(gsampler2DArray *sampler*, vec3 *P*, float *lod*);
gvec4	**textureOffset**(gsampler2D *sampler*, vec2 *P*, ivec2 *offset* [, float *bias*]);
gvec4	**textureOffset**(gsampler3D *sampler*, vec3 *P*, ivec3 *offset* [, float *bias*]);
float	**textureOffset**(sampler2DShadow *sampler*, vec3 *P*, ivec2 *offset* [, float *bias*]);
gvec4	**textureOffset**(gsampler2DArray *sampler*, vec3 *P*, ivec2 *offset* [, float *bias*]);
gvec4	**texelFetch**(gsampler2D *sampler*, ivec2 *P*, int *lod*);
gvec4	**texelFetch**(gsampler3D *sampler*, ivec3 *P*, int *lod*);
gvec4	**texelFetch**(gsampler2DArray *sampler*, ivec3 *P*, int *lod*);
gvec4	**texelFetchOffset**(gsampler2D *sampler*, ivec2 *P*, int *lod*, ivec2 *offset*);
gvec4	**texelFetchOffset**(gsampler3D *sampler*, ivec3 *P*, int *lod*, ivec3 *offset*);
gvec4	**texelFetchOffset**(gsampler2DArray *sampler*, ivec3 *P*, int *lod*, ivec2 *offset*);
gvec4	**textureProjOffset**(gsampler2D *sampler*, vec3 *P*, ivec2 *offset* [, float *bias*]);
gvec4	**textureProjOffset**(gsampler2D *sampler*, vec4 *P*, ivec2 *offset* [, float *bias*]);
gvec4	**textureProjOffset**(gsampler3D *sampler*, vec4 *P*, ivec3 *offset* [, float *bias*]);
float	**textureProjOffset**(sampler2DShadow *sampler*, vec4 *P*, ivec2 *offset* [, float bias]);
gvec4	**textureLodOffset**(gsampler2D *sampler*, vec2 *P*, float *lod*, ivec2 *offset*);
gvec4	**textureLodOffset**(gsampler3D *sampler*, vec3 *P*, float *lod*, ivec3 *offset*);
float	**textureLodOffset**(sampler2DShadow *sampler*, vec3 *P*, float *lod*, ivec2 *offset*);
gvec4	**textureLodOffset**(gsampler2DArray *sampler*, vec3 *P*, float *lod*, ivec2 *offset*);
gvec4	**textureProjLod**(gsampler2D *sampler*, vec3 *P*, float *lod*);
gvec4	**textureProjLod**(gsampler2D *sampler*, vec4 *P*, float *lod*);
gvec4	**textureProjLod**(gsampler3D *sampler*, vec4 *P*, float *lod*);
float	**textureProjLod**(sampler2DShadow *sampler*, vec4 *P*, float *lod*);
gvec4	**textureProjLodOffset**(gsampler2D *sampler*, vec3 *P*, float *lod*, ivec2 *offset*);
gvec4	**textureProjLodOffset**(gsampler2D *sampler*, vec4 *P*, float *lod*, ivec2 *offset*);
gvec4	**textureProjLodOffset**(gsampler3D *sampler*, vec4 *P*, float *lod*, ivec3 *offset*);
float	**textureProjLodOffset**(sampler2DShadow *sampler*, vec4 *P*, float *lod*, ivec2 *offset*);
gvec4	**textureGrad**(gsampler2D *sampler*, vec2 *P*, vec2 *dPdx*, vec2 *dPdy*);
gvec4	**textureGrad**(gsampler3D *sampler*, vec3 *P*, vec3 *dPdx*, vec3 *dPdy*);
gvec4	**textureGrad**(gsamplerCube *sampler*, vec3 *P*, vec3 *dPdx*, vec3 *dPdy*);
float	**textureGrad**(sampler2DShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*);
float	**textureGrad**(samplerCubeShadow *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*);
gvec4	**textureGrad**(gsampler2DArray *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*);
float	**textureGrad**(sampler2DArrayShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*);
gvec4	**textureGradOffset**(gsampler2D *sampler*, vec2 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
gvec4	**textureGradOffset**(gsampler3D *sampler*, vec3 *P*, vec3 *dPdx*, vec3 *dPdy*, ivec3 *offset*);
float	**textureGradOffset**(sampler2DShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
gvec4	**textureGradOffset**(gsampler2DArray *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
float	**textureGradOffset**(sampler2DArrayShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
gvec4	**textureProjGrad**(gsampler2D *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*);
gvec4	**textureProjGrad**(gsampler2D *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*);
gvec4	**textureProjGrad**(gsampler3D *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*);
float	**textureProjGrad**(sampler2DShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*);
gvec4	**textureProjGradOffset**(gsampler2D *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
gvec4	**textureProjGradOffset**(gsampler2D *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
gvec4	**textureProjGradOffset**(gsampler3D *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*, ivec3 *offset*);
float	**textureProjGradOffset**(sampler2DShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);

Fragment Processing Functions [8.9]

Approximated using local differencing.

T **dFdx**(T *p*);	Derivative in *x*
T **dFdy**(T *p*);	Derivative in *y*
T **fwidth**(T *p*);	**abs** (**dFdx** (*p*)) + **abs** (**dFdy** (*p*));