OpenGL ES (Open Graphics Library for Embedded Systems) 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.

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

- **[n.n.n]** refers to sections and tables in the OpenGL ES 3.2 specification.
- **[n.n.n]** refers to sections in the OpenGL ES Shading Language 3.20 specification.

OpenGL ES Command Syntax [2.2]

Commands are formed from a return type, a name, and optionally letters to denote type: i for 32-bit int, i64 for int64, f for 32-bit float, or ui for 32-bit uint, shown in 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

Command Execution

OpenGL Errors [2.3.1]

enum **GetError**(void);
Returns NO_ERROR, OUT_OF_MEMORY, INVALID_FRAMEBUFFER_OPERATION, or one of INVALID_{ENUM, VALUE, OPERATION}

Graphics Reset Recovery [2.3.2]

enum **GetGraphicsResetStatus**(void);
Returns NO_ERROR or one of {GUILTY, INNOCENT, UNKNOWN}_CONTEXT_RESET

Flush and Finish [2.3.3]

void **Flush**(void); void **Finish**(void);

Synchronization

Sync Objects and Fences [4.1]

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

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

Waiting for Sync Objects [4.1.1]

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

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

Sync Object Queries [4.1.3]

void **GetSynciv**(sync *sync*, enum *pname*, sizei *bufSize*, sizei *length*, int *values);
pname: OBJECT_TYPE, SYNC_CONDITION, SYNC_FLAGS, SYNC_STATUS

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

Programs and Shaders

Shader Objects [7.1-2]

uint **CreateShader**(enum *type*);
*type: X*_SHADER, where *X* may be one of COMPUTE, FRAGMENT, GEOMETRY, TESS_{CONTROL, EVALUATION}, VERTEX

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

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

void **ReleaseShaderCompiler**(void);

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

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

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

Program Objects [7.3]

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, PROGRAM_SEPARABLE
value: TRUE, FALSE

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

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

uint **CreateShaderProgramv**(enum *type*, sizei *count*, const char * const * *strings*);
type: See CreateShader

Program Interfaces [7.3.1]

void **GetProgramInterfaceiv**(uint *program*, enum *programInterface*, enum *pname*, int *params*);
programInterface: ATOMIC_COUNTER_BUFFER, BUFFER_VARIABLE, PROGRAM_{INPUT, OUTPUT}, SHADER_STORAGE_BLOCK, TRANSFORM_FEEDBACK_VARYING, UNIFORM[_BLOCK]
pname: ACTIVE_RESOURCES, MAX_NAME_LENGTH, MAX_NUM_ACTIVE_VARIABLES

uint **GetProgramResourceIndex**(uint *program*, enum *programInterface*, const char *name);
programInterface: See GetProgramInterfaceiv, omitting ATOMIC_COUNTER_BUFFER

void **GetProgramResourceName**(uint *program*, enum *programInterface*, uint *index*, sizei *bufSize*, sizei *length*, char *name);
programInterface: See GetProgramResourceIndex

void **GetProgramResourceiv**(uint *program*, enum *programInterface*, uint *index*, sizei *propCount*, const enum *props, sizei *bufSize*, sizei *length*, int *params);
programInterface: See GetProgramInterfaceiv
props: [see Table 7.2]

int **GetProgramResourceLocation**(uint *program*, enum *programInterface*, const char *name);
programInterface: PROGRAM_{INPUT, OUTPUT}, UNIFORM

Program Pipeline Objects [7.4]

void **GenProgramPipelines**(sizei *n*, uint *pipelines);

void **DeleteProgramPipelines**(sizei *n*, const uint *pipelines);

boolean **IsProgramPipeline**(uint *pipeline*);

void **BindProgramPipeline**(uint *pipeline*);

void **UseProgramStages**(uint *pipeline*, bitfield *stages*, uint *program*);
stages: ALL_SHADER_BITS or the bitwise OR of *X*_SHADER_BIT, where *X* may be one of COMPUTE, FRAGMENT, GEOMETRY, TESS_CONTROL, TESS_EVALUATION, VERTEX

void **ActiveShaderProgram**(uint *pipeline*, uint *program*);

Program Binaries [7.5]

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

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

Uniform Variables [7.6]

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

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

void **GetActiveUniform**(uint *program*, uint *index*, sizei *bufSize*, sizei *length*, int *size, enum *type, char *name);
**type* returns: [Table 7.3] FLOAT[_VEC{2, 3, 4}], INT[_VEC{2, 3, 4}], UNSIGNED_INT[_VEC{2, 3, 4}], BOOL[_VEC{2, 3, 4}], FLOAT_MAT{2, 3, 4}, FLOAT_MAT2x{3, 4}, FLOAT_MAT3x{2, 4}, FLOAT_MAT4x{2, 3}, SAMPLER_{2D, 3D, CUBE}, [UNSIGNED_]INT_SAMPLER_{2D, 3D, CUBE}, SAMPLER_{CUBE, 2D[_ARRAY]}_SHADOW, SAMPLER_2D_{ARRAY, MULTISAMPLE}, [UNSIGNED_]INT_SAMPLER_2D_{ARRAY, MULTISAMPLE}, IMAGE_{2D[_ARRAY], 3D, CUBE}, [UNSIGNED_]INT_IMAGE_{2D[_ARRAY], 3D, CUBE}, UNSIGNED_INT_ATOMIC_COUNTER

void **GetActiveUniformsiv**(uint *program*, sizei *uniformCount*, const uint *uniformIndices, enum *pname*, int *params);
pname: [Table 7.6] UNIFORM_*X*, where *X* may be one of ARRAY_STRIDE, BLOCK_INDEX, IS_ROW_MAJOR, MATRIX_STRIDE, NAME_LENGTH, OFFSET, SIZE, TYPE

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_ACTIVE_UNIFORMS, UNIFORM_BLOCK_ACTIVE_UNIFORM_INDICES, UNIFORM_BLOCK_BINDING, UNIFORM_BLOCK_DATA_SIZE, UNIFORM_BLOCK_NAME_LENGTH, UNIFORM_BLOCK_REFERENCED_BY_*X*_SHADER, where *X* may be one of FRAGMENT, GEOMETRY, TESS_CONTROL, TESS_EVALUATION, VERTEX [Table 7.7]

(Continued on next page) ▶

Asynchronous Queries [4.2]

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

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

void **BeginQuery**(enum *target*, uint *id*);
target: ANY_SAMPLES_PASSED[_CONSERVATIVE], PRIMITIVES_GENERATED, TRANSFORM_FEEDBACK_PRIMITIVES_WRITTEN

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

void **EndQuery**(enum *target*);
target: See BeginQuery

void **GetQueryiv**(enum *target*, enum *pname*, int *params);
target: See BeginQuery
pname: must be CURRENT_QUERY

void **GetQueryObjectuiv**(uint *id*, enum *pname*, uint *params);
pname: QUERY_RESULT[_AVAILABLE]

Buffer Objects [6]

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

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

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

Create and Bind Buffer Objects [6.1]

void **BindBuffer**(enum *target*, uint *buffer*);
target: [Table 6.1] *X*_BUFFER, where *X* may be one of ARRAY, ATOMIC_COUNTER, COPY_{READ, WRITE}, {DISPATCH, DRAW}_INDIRECT, ELEMENT_ARRAY, PIXEL_[UN]PACK, SHADER_STORAGE, TRANSFORM_FEEDBACK, UNIFORM

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

void **BindBufferBase**(enum *target*, uint *index*, uint *buffer*);
target: See BindBufferRange

Buffer Object Data Stores [6.2]

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

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

Map/Unmap Buffer Data [6.3]

void ***MapBufferRange**(enum *target*, intptr *offset*, sizeiptr *length*, bitfield *access*);
target: See BindBuffer
access: The logical OR of MAP_*X*_BIT (conditions apply), where *X* may be FLUSH_EXPLICIT, READ, INVALIDATE_{BUFFER, RANGE}, WRITE, UNSYNCHRONIZED

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

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

Copy Between Buffers [6.5]

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

Buffer Object Queries [6.6]

void **GetBufferParameteri[64]v**(enum *target*, enum *pname*,int[64]*data);
target: See BindBuffer
pname: [Table 6.2] BUFFER_ACCESS_FLAGS, BUFFER_MAP_{LENGTH, OFFSET}, BUFFER_MAPPED, BUFFER_SIZE, BUFFER_USAGE

void **GetBufferPointerv**(enum *target*, enum *pname*, void **params);
target: See BindBuffer
pname: must be BUFFER_MAP_POINTER

◀ Programs and Shaders (cont.)

Load Uniform Vars. In Default Uniform Block

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

void **Uniform{1234}{i f ui}v**(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 **ProgramUniform{1234}{i f}**(uint *program*, int *location*, T *value*);

void **ProgramUniform{1234}{i f}v**(uint *program*, int *location*, sizei *count*, const T **value*);

void **ProgramUniform{1234}ui**(uint *program*, int *location*, T *value*);

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

void **ProgramUniformMatrix{234}{f}v**(uint *program*, int *location*, sizei *count*, boolean *transpose*, const T **value*);

void **ProgramUniformMatrix{2x3, 3x2, 2x4, 4x2, 3x4, 4x3}{f}v**(uint *program*, int *location*, sizei *count*, boolean *transpose*, const T **value*);

Uniform Buffer Object Bindings

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

Shader Memory Access [7.11]

void **MemoryBarrier**(bitfield *barriers*);

barriers:
ALL_BARRIER_BITS, or the OR of *X*_BARRIER_BIT, where *X* may be one of: ATOMIC_COUNTER, BUFFER_UPDATE, COMMAND, ELEMENT_ARRAY, FRAMEBUFFER, PIXEL_BUFFER, SHADER_IMAGE_ACCESS, SHADER_STORAGE, TEXTURE_FETCH, TEXTURE_UPDATE, TRANSFORM_FEEDBACK, UNIFORM, VERTEX_ATTRIB_ARRAY

void **MemoryBarrierByRegion**(bitfield *barriers*);

barriers:
ALL_BARRIER_BITS or the OR of *X*_BARRIER_BIT, where *X* may be one of: ATOMIC_COUNTER, FRAMEBUFFER, IMAGE_ACCESS, SHADER_SHADER_STORAGE, TEXTURE_FETCH, UNIFORM

Shader, Program, Pipeline Queries [7.12]

void **GetShaderiv**(uint *shader*, enum *pname*, int **params*);

pname: {COMPILE, DELETE}_STATUS, INFO_LOG_LENGTH, SHADER_{SOURCE_LENGTH, TYPE},

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

pname: ACTIVE_ATOMIC_COUNTER_BUFFERS, ACTIVE_ATTRIBUTES, ACTIVE_UNIFORMS, ACTIVE_{ATTRIBUTE, UNIFORM}_MAX_LENGTH, ACTIVE_UNIFORM_BLOCKS, ACTIVE_UNIFORM_BLOCK_MAX_NAME_LENGTH, ATTACHED_SHADERS, COMPUTE_WORK_GROUP_SIZE, DELETE_STATUS, GEOMETRY_VERTICES_OUT, GEOMETRY_{INPUT, OUTPUT}_TYPE, GEOMETRY_SHADER_INVOCATIONS, INFO_LOG_LENGTH, LINK_STATUS, PROGRAM_BINARY_RETRIEVABLE_HINT, PROGRAM_SEPARABLE, TRANSFORM_FEEDBACK_BUFFER_MODE, TRANSFORM_FEEDBACK_VARYINGS, TRANSFORM_FEEDBACK_VARYING_MAX_LENGTH, TESS_CONTROL_OUTPUT_VERTICES, TESS_GEN_MODE, TESS_GEN_SPACING, TESS_GEN_VERTEX_ORDER, TESS_GEN_POINT_MODE, VALIDATE_STATUS,

void **GetProgramPipelineiv**(uint *pipeline*, enum *pname*, int **params*);

pname: ACTIVE_PROGRAM, INFO_LOG_LENGTH, VALIDATE_STATUS, or *X*_SHADER , where *X* may be one of COMPUTE, FRAGMENT, GEOMETRY, VERTEX, TESS_CONTROL, TESS_EVALUATION

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

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

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

void **GetProgramPipelineInfoLog**(uint *pipeline*, 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: {FRAGMENT, VERTEX}_SHADER

precisiontype: {LOW, MEDIUM, HIGH}_{FLOAT, INT}

void **GetUniform{f i ui}v**(uint *program*, int *location*, T **params*);

void **GetnUniform{f i ui}v**(uint *program*, int *location*, T **params*);

Textures and Samplers [8]

void **ActiveTexture**(enum *texture*);

texture: TEXTURE*i* (where *i* is [0, max (MAX_COMBINED_TEXTURE_IMAGE_UNITS)-1])

Texture Objects [8.1]

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

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

target:
TEXTURE_2D[_ARRAY], TEXTURE_3D, TEXTURE_2D_MULTISAMPLE[_ARRAY], TEXTURE_BUFFER, TEXTURE_CUBE_MAP[_ARRAY]

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

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

Sampler Objects [8.2]

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

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

void **SamplerParameter{i f}**(uint *sampler*, enum *pname*, T *param*);

pname: TEXTURE_*X*, where *X* may be one of COMPARE_{MODE, FUNC}, {MIN, MAG}_FILTER, {MIN, MAX}_LOD, WRAP_{S, T, R} [Table 20.11]

void **SamplerParameter{i f}v**(uint *sampler*, enum *pname*, const T **params*);

pname: ***See SamplerParameter{if}***

void **SamplerParameterI{i ui}v**(uint *sampler*, enum *pname*, const T **params*);

pname: ***See SamplerParameter{if}***

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

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

Sampler Queries [8.3]

void **GetSamplerParameter{i f}v**(uint *sampler*, enum *pname*, T **params*);

pname: ***See SamplerParameter{if}***

void **GetSamplerParameterI{i ui}v**(uint *sampler*, enum *pname*, T **params*);

pname: ***See SamplerParameter{if}***

Pixel Storage Modes and Pixel Buffer Objects [8.4.1]

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

pname: [Tables 8.1, 18.1]
[UN]PACK_ALIGNMENT, UNPACK_IMAGE_HEIGHT, [UN]PACK_ROW_LENGTH, UNPACK_SKIP_IMAGES, [UN]PACK_SKIP_PIXELS, [UN]PACK_SKIP_ROWS

Texture Image Spec. [8.5]

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_2D_ARRAY, TEXTURE_3D, TEXTURE_CUBE_MAP_ARRAY

format:
ALPHA, DEPTH_{COMPONENT, STENCIL}, LUMINANCE,LUMINANCE_ALPHA, RGBA, RGB, RG, RED, {RGBA, RGB, RG, RED}_INTEGER, STENCIL_INDEX

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: Alpha, LUMINANCE_ALPHA, LUMINANCE, DEPTH_COMPONENT{16, 24, 32F} 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, SRGB8, SRGB8_ALPHA8, RGB9_E5, RGB10_A2, RGB10_A2UI, RGB16I, RGB16UI, RGB16F, RGB32I, RGB32UI, RGB32F, RGBA, RGBA4, RGBA8, RGBA8I, RGBA8UI, RGBA8_SNORM, RGBA16I, RGBA16UI, RGBA16F, RGBA32I, RGBA32UI, RGBA32F, R11F_G11F_B10F

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_NEGATIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}

internalformat: ***See TexImage3D***

format, type: ***See TexImage3D***

Alternate Texture Image Spec. [8.6]

void **CopyTexImage2D**(enum *target*, int *level*, enum *internalformat*, int *x*, int *y*, sizei *width*, sizei *height*, int *border*);

target: ***See TexImage2D***

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_2D_ARRAY, TEXTURE_3D

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: ***See TexImage2D***

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_2D_ARRAY, TEXTURE_3D

format, type: ***See TexImage3D***

void **CopyTexSubImage2D**(enum *target*, int *level*, int *xoffset*, int *yoffset*, int *x*, int *y*, sizei *width*, sizei *height*);

target: ***See TexImage2D***

Compressed Texture Images [8.7]

void **CompressedTexImage2D**(enum *target*, int *level*, enum *internalformat*, sizei *width*, sizei *height*, int *border*, sizei *imageSize*, const void **data*);

target: ***See TexImage2D***

internalformat: [Table 8.17] COMPRESSED_*X*, where *X* may be one of [SIGNED_]R11_EAC, [SIGNED_]RG11_EAC, [S]RGB8_ETC2, [S]RGB8_PUNCHTHROUGH_ALPHA1_ETC2, RGBA8_ETC2_EAC, SRGB8_ALPHA8_ETC2_EAC, RGBA_ASTC_*dim*, or SRGB8_ALPHA8_ASTC_*dim* (where *dim* may be one of 4x4, 5x4, 5x5, 6x5, 6x6, 8x5, 10x5, 10x6, 10x8, 10x10, 12x10, 12x12)

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

target: Any compressed internal format from [Table 18.7]

internalformat: Any ASTC compressed internal format from [Table 18.7]: COMPRESSED_{RGBA, SRGB8_ALPHA8}_ASTC_*X*, where *X* may be one of 4x4, 5x4, 5x5, 6x5, 6x6, 8x5, 8x6, 8x8, 10x5, 10x6, 10x8, 10x10, 12x10, 12x12

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

target: ***See TexImage2D***

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: TEXTURE_2D_ARRAY, TEXTURE_3D

Multisample Textures [8.8]

void **TexStorage2DMultisample**(enum *target*, sizei *samples*, int *sizedinternalformat*, sizei *width*, sizei *height*, boolean *fixedsamplelocations*);

target: TEXTURE_2D_MULTISAMPLE

sizedinternalformat: (Supported when *samples* = 1) DEPTH{24, 32F}_STENCIL8, DEPTH_COMPONENT{16, 24, 32F}, R11F_G11F_B10F, R16{F, I, UI}, R32{F, I, UI}, R8, R8{I, UI}, RG16{F, I, UI}, RG32{F, I, UI}, RG8, RG8{I, UI}, RGB10_A2, RGB10_A2UI, RGB8, RGB565, RGB5_A1, RGBA16{F, I, UI}, RGBA32{F, I, UI}, RGBA4, RGBA8, RGBA8{I, UI}, SRGB8_ALPHA8, STENCIL_INDEX8

void **TexStorage3DMultisample**(enum *target*, sizei *samples*, int *sizedinternalformat*, sizei *width*, sizei *height*, sizei *depth*, boolean *fixedsamplelocations*);

target: TEXTURE_2D_MULTISAMPLE_ARRAY

sizedinternalformat: ***See TexStorage2DMultisample***

Buffer Textures [8.9]

void **TexBufferRange**(enum *target*, enum *internalformat*, uint *buffer*, intptr *offset*, sizeiptr *size*);

target: TEXTURE_BUFFER

internalformat:
Any sized internal format from Table 8.18

void **TexBuffer**(enum *target*, enum *internalformat*, uint *buffer*);

target, internalformat: ***See TexBufferRange***

Texture Parameters [8.10]

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

target:
TEXTURE_{2D, 3D}, TEXTURE_2D_{ARRAY, MULTISAMPLE}, TEXTURE_2D_MULTISAMPLE_ARRAY, TEXTURE_CUBE_MAP[_ARRAY]

pname: [Table 8.19]
DEPTH_STENCIL_TEXTURE_MODE, TEXTURE_BORDER_COLOR, TEXTURE_{BASE, MAX}_LEVEL, TEXTURE_COMPARE_{MODE, FUNC}, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_{MIN, MAX}_LOD, TEXTURE_SWIZZLE_{R,G,B,A}, TEXTURE_WRAP_{S,T,R}

void **TexParameter{i f}v**(enum *target*, enum *pname*, const T **params*);

target, pname: ***See TexParameter{i f}***

void **TexParameterI{i ui}v**(uint *texture*, enum *pname*, const T **params*);

pname: ***See TexParameter{i f}***

texture: ***See target for TexParameter{i f}***

(Continued on next page) ▶

◀ Textures, Samplers (cont.)

Texture Queries [8.11]

void **GetTexParameter{i f}v**(enum *target*, enum *pname*, T * *params*);
target: TEXTURE_{2D, 3D}, TEXTURE_2D_{ARRAY, MULTISAMPLE} TEXTURE_2D_MULTISAMPLE_ARRAY, TEXTURE_CUBE_MAP[_ARRAY]
pname: *See TexParameter{i f}v*, plus IMAGE_FORMAT_COMPATIBILITY_TYPE, TEXTURE_IMMUTABLE_{FORMAT, LEVELS}

void **GetTexParameterI{i ui}v**(enum *target*, enum *pname*, T * *params*);
target: *See GetTexParameter{i f}v*

void **GetTexLevelParameter{i f}v**(enum *target*, int *level*, enum *pname*, T *params);
target: TEXTURE_2D[_MULTISAMPLE], TEXTURE_{2D, CUBE_MAP}_ARRAY, TEXTURE_2D_MULTISAMPLE_ARRAY,, TEXTURE_BUFFER, TEXTURE_3D TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}
pname: [Table 21.11] TEXTURE_*Y*, where *Y* may be one of BUFFER_DATA_STORE_BINDING, BUFFER_{OFFSET, SIZE}, COMPRESSED, DEPTH, HEIGHT, INTERNAL_FORMAT, FIXED_SAMPLE_LOCATIONS, SAMPLES, SHARED_SIZE, STENCIL_SIZE, WIDTH; or *X*_{SIZE, TYPE}, where *X* may be one of ALPHA, RED, GREEN, BLUE, DEPTH

Manual Mipmap Generation [8.14.4]

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

Immutable-Format Tex. Images [8.18]

void **TexStorage2D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*, sizei *height*);
target: TEXTURE_2D, TEXTURE_CUBE_MAP
internalformat: *See TexImage3D*

void **TexStorage3D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*, sizei *height*, sizei *depth*);
target: TEXTURE_2D_ARRAY, TEXTURE_3D, TEXTURE_CUBE_MAP_ARRAY
internalformat: *See TexImage3D*

Texture Image Loads/Stores [8.22]

void **BindImageTexture**(uint *unit*, uint *texture*, int *level*, boolean *layered*, int *layer*, enum *access*, enum *format*);
access: READ_ONLY, READ_WRITE, WRITE_ONLY
format: [Table 8.27] R32{I, F, UI}, RGBA32{I, F, UI}, RGBA16{I, F, UI}, RGBA8 , RGBA8{I, UI}, RGBA8_SNORM

Patches and Vertices

Separate Patches [10.1.12]

Specify the fixed number of vertices in each patch in the series.

void **PatchParameteri**(enum *pname*, int *value*);
pname: must be PATCH_VERTICES

Current Vertex Attribute Values [10.2.1]

Specify generic attributes with components of type float (VertexAttrib*), int, or uint (VertexAttribI*).

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

Generic Vertex Attributes [10.3.1]

void **VertexAttribFormat**(uint *attribindex*, int *size*, enum *type*, boolean *normalized*, unit *relativeoffset*);
type: FIXED, [UNSIGNED_]BYTE, [UNSIGNED_]INT, [HALF_]FLOAT, [UNSIGNED_]INT_2_10_10_10_REV, [UNSIGNED_]SHORT

void **VertexAttribIFormat**(uint *attribindex*, int *size*, enum *type*, unit *relativeoffset*);
type: *See VertexAttribFormat*

void **BindVertexBuffer**(uint *bindingindex*, uint *buffer*, intptr *offset*, sizei *stride*);

void **VertexAttribBinding**(uint *attribindex*, uint *bindingindex*);

void **VertexAttribPointer**(uint *index*, int *size*, enum *type*, boolean *normalized*, sizei *stride*, const void *pointer);
type: *See VertexAttribFormat*

void **VertexAttribIPointer**(uint *index*, int *size*, enum *type*, sizei *stride*, const void *pointer);
type: *See VertexAttribIFormat*
index: [0, MAX_VERTEX_ATTRIBS - 1]

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

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

Vertex Attribute Divisors [10.3.2]

void **VertexBindingDivisor**(uint *bindingindex*, uint *divisor*);

void **VertexAttribDivisor**(uint *index*, uint *divisor*);

Primitive Restart [10.3.4]

Enable/Disable/IsEnabled(*target*);
target: PRIMITIVE_RESTART_FIXED_INDEX

Vertex Array Objects [10.4]

All states related to definition of data used by vertex processor is in a vertex array object.

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

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

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

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

Drawing Commands [10.5]

For all the functions in this section:
mode: LINE_LOOP, LINE_[STRIP_]ADJACENCY, LINES, LINES_ADJACENCY, PATCHES TRIANGLE_FAN, POINTS[_TRIANGLES_ADJACENCY], TRIANGLES, TRIANGLE_STRIP[_ADJACENCY]
type: UNSIGNED_{BYTE, SHORT, INT}

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

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

void **DrawArraysIndirect**(enum *mode*, const void *indirect);

void **DrawElements**(enum *mode*, sizei *count*, enum *type*, const void *indices);

void **DrawElementsInstanced**(enum *mode*, sizei *count*, enum *type*, const void *indices, sizei *instancecount*);

void **DrawRangeElements**(enum *mode*, uint *start*, uint *end*, sizei *count*, enum *type*, const void *indices);

void **DrawElementsBaseVertex**(enum *mode*, sizei *count*, enum *type*, const void *indices, int *basevertex*);

void **DrawRangeElementsBaseVertex**(enum *mode*, uint *start*, uint *end*, sizei *count*, enum *type*, const void *indices, int *basevertex*);

void **DrawElementsInstancedBaseVertex**(enum *mode*, sizei *count*, enum *type*, const void *indices, sizei *instancecount*, int *basevertex*);

void **DrawElementsIndirect**(enum *mode*, enum *type*, const void *indirect);

Vertex Array Queries [10.6]

void **GetVertexAttrib{f i}v**(uint *index*, enum *pname*, T *params);
pname: CURRENT_VERTEX_ATTRIB, VERTEX_ATTRIB_[BUFFER_]BINDING, VERTEX_ATTRIB_RELATIVE_OFFSET, or VERTEX_ATTRIB_ARRAY_*X*, where *X* may be one of DIVISOR, ENABLED, INTEGER, NORMALIZED, SIZE, STRIDE, TYPE

void **GetVertexAttribI{i ui}v**(uint *index*, enum *pname*, T *params);
pname: See *GetVertexAttrib{f i}v*

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

Framebuffer Objects

Binding and Managing [9.2]

void **BindFramebuffer**(enum *target*, uint *framebuffer*);
target: [DRAW_, READ_]FRAMEBUFFER

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

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

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

Framebuffer Object Parameters [9.2.1]

void **FramebufferParameteri**(enum *target*, enum *pname*, int *param*);
target: [DRAW_, READ_]FRAMEBUFFER
pname: FRAMEBUFFER_DEFAULT_*X* where *X* may be one of FIXED_SAMPLE_LOCATIONS, HEIGHT, LAYERS, SAMPLES, WIDTH

Framebuffer Object Queries [9.2.3]

void **GetFramebufferParameteriv**(enum *target*, enum *pname*, int *params);
target: [DRAW_, READ_]FRAMEBUFFER
pname: *See FramebufferParameteri*

void **GetFramebufferAttachmentParameteriv**(enum *target*, enum *attachment*, enum *pname*, int *params);
target: [DRAW_, READ_]FRAMEBUFFER
attachment: BACK, COLOR_ATTACHMENT*i*, DEPTH, STENCIL, {DEPTH, STENCIL, DEPTH_STENCIL}_ATTACHMENT
pname: FRAMEBUFFER_ATTACHMENT_*X*, where *X* may be OBJECT_{NAME, TYPE}, COLOR_ENCODING, COMPONENT_TYPE, {RED, GREEN, BLUE}_SIZE, {ALPHA, DEPTH, STENCIL}_SIZE, LAYERED, TEXTURE_{LAYER, LEVEL, CUBE_MAP_FACE}

Renderbuffer Objects [9.2.4]

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

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

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

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

void **RenderbufferStorageMultisample**(enum *target*, sizei *samples*, enum *internalformat*, sizei *width*, sizei *height*);
target: must be RENDERBUFFER
internalformat: *See sizedinternalformat for TexStorage2DMultisample*

void **RenderbufferStorage**(enum *target*, enum *internalformat*, sizei *width*, sizei *height*);
target: must be RENDERBUFFER
internalformat: *See TexStorage2DMultisample*

Renderbuffer Object Queries [9.2.6]

void **GetRenderbufferParameteriv**(enum *target*, enum *pname*, int *params);
target: must be RENDERBUFFER
pname: [Table 20.16] RENDERBUFFER_*X*, where *X* may be one of HEIGHT, INTERNAL_FORMAT, SAMPLES, WIDTH, *Y*_SIZE, where *Y* may be one of ALPHA, RED, GREEN, BLUE, DEPTH, STENCIL

Attaching Renderbuffer Images [9.2.7]

void **FramebufferRenderbuffer**(enum *target*, enum *attachment*, enum *renderbuffertarget*, uint *renderbuffer*);
target: [DRAW_, READ_]FRAMEBUFFER
attachment: [Table 9.1] {DEPTH, STENCIL, DEPTH_STENCIL}_ATTACHMENT, COLOR_ATTACHMENT*i* where *i* is [0, MAX_COLOR_ATTACHMENTS - 1]
renderbuffertarget: RENDERBUFFER if *renderbuffer* is non-zero, else undefined

Attaching Texture Images [9.2.8]

void **FramebufferTexture**(enum *target*, enum *attachment*, uint *texture*, int *level*);
target, attachment: *See FramebufferRenderbuffer*

void **FramebufferTexture2D**(enum *target*, enum *attachment*, enum *textarget*, uint *texture*, int *level*);
textarget: TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}, TEXTURE_{2D, 2D_MULTISAMPLE} if *texture* is zero, else undefined
target, attachment: *See FramebufferRenderbuffer*

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

Framebuffer Completeness [9.4.2]

enum **CheckFramebufferStatus**(enum *target*);
target: [DRAW_, READ_]FRAMEBUFFER
returns: FRAMEBUFFER_COMPLETE or a constant indicating the violating value

Vertex Attributes [11.1]

Vertex shaders operate on array of 4-component items numbered from slot 0 to MAX_VERTEX_ATTRIBS - 1.

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

void **GetActiveAttrib**(uint *program*, uint *index*, sizei *bufSize*, sizei *length, int *size, enum *type, char *name);

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

Vertex Shader Variables [11.1.2]

void **TransformFeedbackVaryings**(uint *program*, sizei *count*, const char * const *varyings, enum *bufferMode*);
bufferMode: {INTERLEAVED, SEPARATE}_ATTRIBS

void **GetTransformFeedbackVarying**(uint *program*, uint *index*, sizei *bufSize*, sizei *length, sizei *size, enum *type, char *name);
*type returns NONE, *BOOL, BOOL_{VEC2, VEC3, VEC4},* FLOAT[_VEC*n*], FLOAT_MAT*nxm*, FLOAT_MAT*n*, [UNSIGNED_]INT, [UNSIGNED_]INT_VEC*n*,

Shader Validation [11.1.3.11]

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

Vertex Post-Processing [12]

Transform Feedback [12.1]

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

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

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

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

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

void **EndTransformFeedback**(void);

void **PauseTransformFeedback**(void);

void **ResumeTransformFeedback**(void);

Controlling Viewport [12.5.1]

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

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

Shader Execution [14.2.3]

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

Per-Fragment Operations

Scissor Test [13.8.2]

Enable/Disable(SCISSOR_TEST);

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

Multisample Fragment Ops. [13.8.3]

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

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

void **SampleMaski**(uint *maskNumber*, bitfield *mask*);

Stencil Test [15.1.2]

Enable/Disable(STENCIL_TEST);

void **StencilFunc**(enum *func*, int *ref*, uint *mask*);
func:
ALWAYS, EQUAL, GEQUAL, GREATER, LEQUAL, LESS, NEVER, NOTEQUAL

void **StencilFuncSeparate**(enum *face*, enum *func*, int *ref*, uint *mask*);
func: See StencilFunc
face: BACK, FRONT, FRONT_AND_BACK

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

void **StencilOpSeparate**(enum *face*, enum *sfail*, enum *dpfail*, enum *dppass*);
face: BACK, FRONT, FRONT_AND_BACK
sfail, dpfail, dppass:
DECR, DECR_WRAP, INCR, INCR_WRAP, INVERT, KEEP, REPLACE, ZERO

Depth Buffer Test [15.1.3]

Enable/Disable(DEPTH_TEST);

void **DepthFunc**(enum *func*);
func: See StencilFunc

Blending [15.1.5]

void **Enablei**(enum *target*, uint *index*);

void **Disablei**(enum *target*, uint *index*);
target: must be BLEND

Enable/Disable/IsEnabled(BLEND);

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

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

void **BlendEquationSeparate**(enum *modeRGB*, enum *modeAlpha*);
mode, modeRGB, modeAlpha:
FUNC_{ADD, SUBTRACT, REVERSE_SUBTRACT}, MAX, MIN

void **BlendEquationi**(uint *buf*, enum *mode*);

void **BlendEquationSeparatei**(uint *buf*, enum *modeRGB*, enum *modeAlpha*);
modeRGB, modeAlpha: See BlendEquationSeparate

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

void **BlendFuncSeparate**(enum *srcRGB*, enum *dstRGB*, enum *srcAlpha*, enum *dstAlpha*);
src, dst, srcRGB, dstRGB, srcAlpha, dstAlpha:
{CONSTANT, DST, SRC}_COLOR,
{CONSTANT, DST, SRC}_ALPHA,
ONE, ONE_MINUS_SRC_{ALPHA, COLOR},
ONE_MINUS_{CONSTANT, DST}_ALPHA ,
ONE_MINUS_{CONSTANT, DST}_COLOR,
SRC_ALPHA_SATURATE, ZERO

void **BlendFunci**(uint *buf*, enum *src*, enum *dst*);

void **BlendFuncSeparatei**(uint *buf*, enum *srcRGB*, enum *dstRGB*, enum *srcAlpha*, enum *dstAlpha*);
modeRGB, modeAlpha: See BlendFuncSeparate

void **BlendBarrier**(void);

Dithering [15.1.7]

Enable/Disable/IsEnabled(DITHER);

Reading and Copying Pixels and Images

Reading Pixels [16.1]

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 **ReadPixels**(int *x*, int *y*, sizei *width*, sizei *height*, enum *format*, enum *type*, void **data*);
format, type:
- *format:* RGBA + *type*: UNSIGNED_BYTE (normalized fixed-point read buffer);
- *format:* RGBA + *type*: FLOAT (floating-point read buffer);
- *format:* RGBA_INTEGER + *type*: INT (integer read buffer);
- *format:* RGBA_INTEGER + *type*: UNSIGNED_INT (unsigned integer read buffer);
- *Implementation-dependent* combination of *format* + *type* (query for IMPLEMENTATION_COLOR_READ_FORMAT and IMPLEMENTATION_COLOR_READ_TYPE ES constants).

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

Copying Pixels [16.1.2]

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

Copying Between Images [16.2.2]

void **CopyImageSubData**(uint *srcName*, enum *srcTarget*, int *srcLevel*, int *srcX*, int *srcY*, int *srcZ*, uint *dstName*, enum *dstTarget*, int *dstLevel*, int *dstX*, int *dstY*, int *dstZ*, sizei *srcWidth*, sizei *srcHeight*, sizei srcDepth);
srcTarget, dstTarget: TEXTURE_*X*, where *X* may be on of 2D, 2D_{ARRAY, MULTISAMPLE}, 2D_MULTISAMPLE_ARRAY, 3D, CUBE_MAP, CUBE_MAP_ARRAY,

See [Table 16.3] for more information.

Rasterization

Primitive Bounding Box [13.2]

void **PrimitiveBoundingBox**(float *minX*, float *minY*, float *minZ*, float *minW*, float *maxX*, float *maxY*, float *maxZ*, float *maxW*);

Multisampling [13.4]

Use to antialias points and lines.

void **GetMultisamplefv**(enum *pname*, uint *index*, float **val*);
pname: SAMPLE_POSITION

Sample Shading [13.4.1]

void **MinSampleShading**(float *value*);

Points [13.5]

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

Line Segments [13.6]

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

Polygons [13.7]

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

Enable(CULL_FACE)
Disable(CULL_FACE)
IsEnabled(CULL_FACE)

void **CullFace**(enum *mode*);
mode: FBACK, RONT, FRONT_AND_BACK

Enable(POLYGON_OFFSET_FILL)
Disable(POLYGON_OFFSET_FILL)
IsEnabled(POLYGON_OFFSET_FILL)

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

Whole Framebuffer Operations

Selecting Buffers for Writing [15.2.1]

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 [15.2.2]

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

void **ColorMaski**(uint *buf*, 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 [15.2.3]

void **Clear**(bitfield *buf*);
buf: Zero or Bitwise OR of {COLOR, DEPTH, STENCIL}_BUFFER_BIT

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

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

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

void **ClearBuffer{i f 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

Invalidating Framebuffer Contents [15.2.4]

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

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

Debug [18]

Enable/Disable(DEBUG_OUTPUT);

void **DebugMessageCallback**(DEBUGPROC *callback*, const void **userParam*);
callback prototype:
void **callback**(enum *source*, enum *type*, uint *id*, enum *severity*, sizei *length*, const char **message*, const void **userParam*);
source: [Table 18.1] DEBUG_SOURCE_*X*, where *X* may be one of API, APPLICATION, OTHER, SHADER_COMPILER, THIRD_PARTY, WINDOW_SYSTEM
type: [Table 18.2] DEBUG_TYPE_*X*, where *X* may be one of ERROR, MARKER, PORTABILITY, {DEPRECATED, UNDEFINED}_BEHAVIOR, PERFORMANCE, {PUSH, POP}_GROUP, OTHER
severity: [Table 18.3] DEBUG_SEVERITY_*X*, where *X* may be one of HIGH, MEDIUM, LOW, NOTIFICATION

void **DebugMessageControl**(enum *source*, enum *type*, enum *severity*, sizei *count*, const uint **ids*, boolean *enabled*);
source, type, severity: See DebugMessageCallback or DONT_CARE

void **DebugMessageInsert**(enum *source*, enum *type*, uint *id*, enum *severity*, int *length*, const char **buf*);
type, severity: See DebugMessageCallback
source: See DebugMessageCallback or DEBUG_SOURCE_{APPLICATION, THIRD_PARTY}

void **PushDebugGroup**(enum *source*, uint *id*, sizei *length*, const char **message*);
source:
DEBUG_SOURCE_APPLICATION,
DEBUG_SOURCE_THIRD_PARTY

void **PopDebugGroup**(void);

void **ObjectLabel**(enum *identifier*, uint *name*, sizei *length*, const char **label*);
identifier:
[Table 18.4] BUFFER, FRAMEBUFFER, PROGRAM, PROGRAM_PIPELINE, QUERY, RENDERBUFFER, SAMPLER, SHADER, TEXTURE, TRANSFORM_FEEDBACK, VERTEX_ARRAY

void **ObjectPtrLabel**(void **ptr*, sizei *length*, const char **label*);

Enable/Disable(DEBUG_OUTPUT_SYNCHRONOUS);

uint **GetDebugMessageLog**(uint *count*, sizei *bufSize*, enum **sources*, enum **types*, uint **ids*, enum **severities*, sizei **lengths*, char **messageLog*);
sources, types, severities returns:
See DebugMessageCallback

void **GetObjectLabel**(enum *identifier*, uint *name*, sizei *bufSize*, sizei **length*, char **label*);
identifier: See ObjectLabel

void **GetObjectPtrLabel**(void **ptr*, sizei *bufSize*, size **length*, char **label*);

Compute Shaders [17]

void **DispatchCompute**(uint *num_groups_x*, uint *num_groups_y*, uint *num_groups_z*);

void **DispatchComputeIndirect**(intptr *indirect*);

Hints [19.1]

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

Context State Queries

A complete list of symbolic constants for states is shown in the tables in [21].

Simple Queries [20.1]

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 **GetBooleani_v**(enum *target*, uint *index*, boolean *data);

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

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

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

boolean **IsEnabledi**(enum *target*, uint *index*);

target: must be BLEND

void **GetPointerv**(enum *pname*, void **params);

pname: DEBUG_CALLBACK_FUNCTION, DEBUG_CALLBACK_USER_PARAM

String Queries [20.2]

ubyte ***GetString**(enum *name*);

name: EXTENSIONS, RENDERER, [SHADING_LANGUAGE_]VERSION, VENDOR

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

name: must be EXTENSIONS

Internal Format Queries [20.3]

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

target:
RENDERBUFFER, TEXTURE_2D_MULTISAMPLE[_ARRAY]

internalformat:
See RenderbufferStorageMultisample

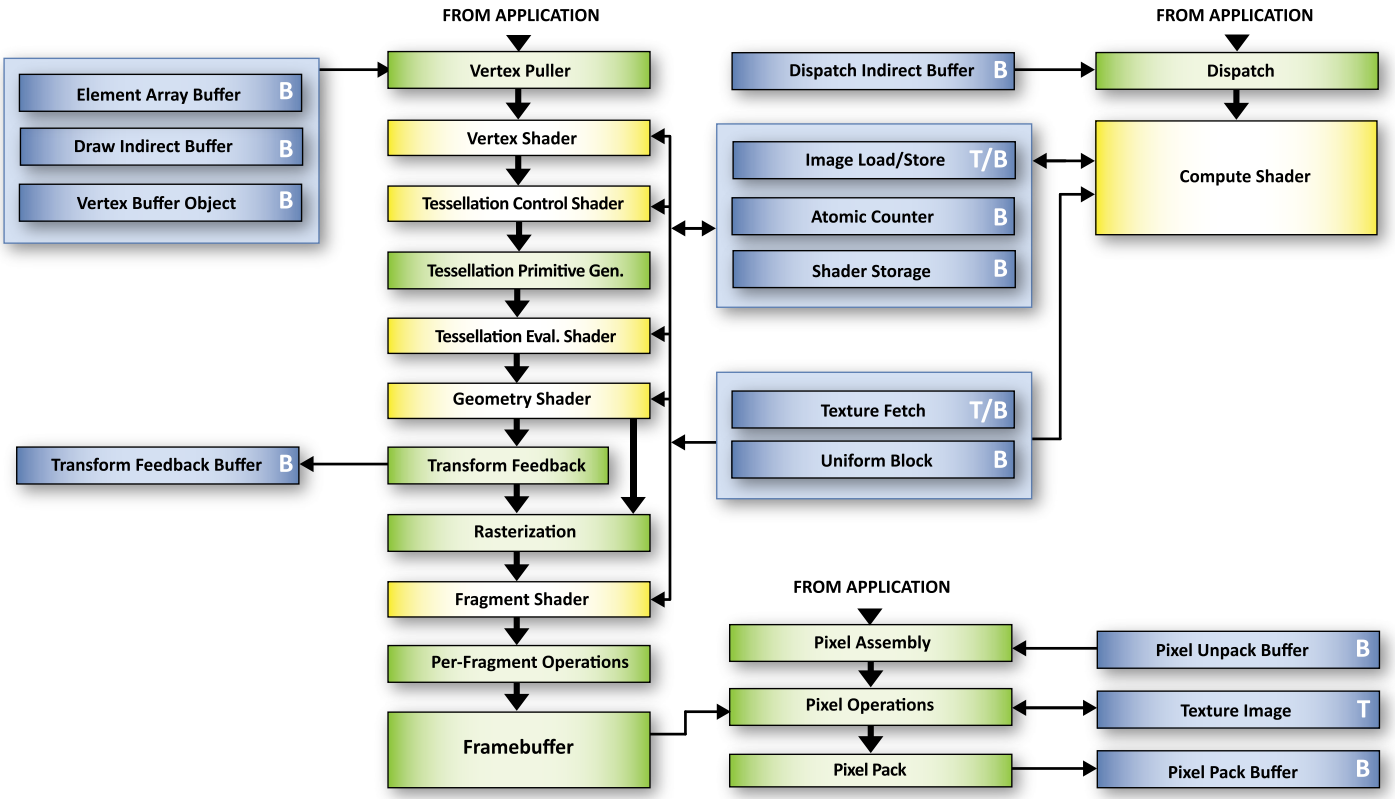
pname:
NUM_SAMPLES_COUNTS, SAMPLES

OpenGL ES Pipeline

A typical program that uses OpenGL ES begins with calls to open a window into the framebuffer into which the program will draw. Calls are made to allocate a GL ES context which is then associated with the window, then OpenGL ES commands can be issued.

The heavy black arrows in this illustration show the OpenGL ES pipeline and indicate data flow.

- Blue blocks indicate various buffers that feed or get fed by the OpenGL ES pipeline.
- Green blocks indicate fixed function stages.
- Yellow blocks indicate programmable stages.
- T Texture binding
- Buffer binding



Notes

The OpenGL® ES Shading Language is three closely-related languages 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 3.20 specification at www.khronos.org/registry/gles/

Basic Types [4.1]

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

Transparent Types

void	no 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 Opaque Types

sampler2D, image2D	access a 2D texture/image
sampler3D, image3D	access a 3D texture/image
samplerCube, imageCube	access cube mapped texture/image
samplerCubeShadow	access cube map depth texture w/comparison
sampler2DShadow	access 2D depth texture with comparison
sampler2DArray, image2DArray	access 2D array texture, image
sampler2DArrayShadow	access 2D array depth texture with comparison
sampler2DMS	access a 2D multisample texture
samplerBuffer, imageBuffer	access a buffer texture/image
samplerCubeArray, imageCubeArray	access a cube map array texture/image
samplerCubeArrayShadow	access a cube map array depth texture with comparison
sampler2DMSArray	access a 2D multisample array texture

Signed Integer Opaque Types

isampler2D, iimage2D	access an integer 2D texture/image
isampler3D, iimage3D	access an integer 3D texture/image
isamplerCube, iimageCube	access integer cube mapped texture/image
isampler2DArray, iimage2DArray	access integer 2D array texture/image
isampler2DMS	access an integer 2D multisample texture
isamplerBuffer, iimageBuffer	access an integer buffer texture/image
isamplerCubeArray iimageCubeArray	access an integer cube map array texture/image
isampler2DMSArray	access an integer 2D multisample array texture

Unsigned Integer Opaque Types

usampler2D, uimage2D	access unsigned integer 2D texture/image
usampler3D, uimage3D	access unsigned integer 3D texture/image
usamplerCube, uimageCube	access unsigned integer cube mapped texture/image
usampler2DArray, uimage2DArray	access unsigned integer 2D array texture/image
atomic_uint	access an unsigned atomic counter
usampler2DMS	access unsigned integer 2D multisample texture
usamplerBuffer, uimageBuffer	access an unsigned integer buffer texture/image
usamplerCubeArray uimageCubeArray	access an unsigned integer cube map array texture/image
usampler2DMSArray	access an unsigned integer 2D multisample array texture/image

Structures and Arrays [4.1.8, 4.1.9]

Structures	struct *type-name* {
	  members
	} *struct-name*[]; // optional variable decl., 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 320 es" must appear in the first line of a shader program written in GLSL ES version 3.20. 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.: 320
GL_ES	Defined and set to integer 1 if running on an OpenGL-ES Shading Language.

Qualifiers

Storage Qualifiers [4.3, 4.5]

Variable declarations may be preceded by one storage qualifier specified in front of the type.

const	Compile-time constant, or read-only function parameter
in	Linkage into a shader from a previous stage
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
buffer	Buffer object
shared	Compute shader storage shared across local workgroup

Auxiliary Storage Qualifiers

Some input and output qualified variables can be qualified with at most one additional auxiliary storage qualifier.

centroid	Centroid-based interpolation
sample	Per-sample interpolation
patch	Per-tessellation-patch attributes

Interpolation Qualifiers

Shader inputs and outputs can be further qualified with one of these interpolation qualifiers.

smooth	Perspective-corrected interpolation
flat	No interpolation

Uniform Variables [4.3.5]

Used to declare read-only global variables whose values are the same across the entire primitive being processed, for example:
uniform vec4 lightPosition;

Buffer Qualifier and Interface Blocks [4.3.7-9]

A group of **uniform** or **buffer** variable declarations. Buffer variables may only be declared inside interface blocks. Example:

```
buffer BufferName {   // externally visible name of buffer
    int count;        // typed, shared memory...
    ...               // ...
    vec4 v[];         // last element may be an unsized array
                      // until after link time (dynamically sized)
} Name;               // name of block within the shader
```

Layout Qualifiers [4.4]

The following table shows the kinds of declarations each layout qualifier may be applied to.

Layout Qualifier	Qualifier Only	Invalidated Variable	Block	Block Member	Allowed Interfaces
shared, packed, std140, std430	X		X		**uniform/buffer**
row_major, column_major	X		X	X	
binding =		opaque types only	X		
offset =		atomic_uint only			
location =		X			
location =		X	X	X	all **in**/**out**, except for compute
triangles, quads, isolines	X				tessellation evaluation **in**
equal_spacing, fractional_{even, odd}_spacing	X				tessellation evaluation **in**
cw, ccw	X				tessellation evaluation **in**
point_mode	X				tessellation evaluation **in**
points	X				geometry **in**/**out**
points, lines, triangles, {lines, triangles}_adjacency	X				geometry **in**
invocations =	X				geometry **in**
early_fragment_tests	X				fragment **in**
local_size_{x, y, z} =	X				compute **in**
vertices	X				tessellation control **out**
[points], line_strip, triangle_strip	X				geometry **out**
max_vertices =	X				geometry **out**
rgba{32f, 16f}, r32f, rgba8[_snorm], rgba{32i, 16i, 8i}, r32i, rgba{32ui, 16ui, 8ui}, r32ui		image types only			uniform
blend_support_X, where *X* may be one of: multiply, screen, overlay, darken, lighten, colordodge, colorburn, hardlight, softlight, difference, exclusion, hsl_{hue, saturation, color, luminosity, equations}		X			fragment **out**

(Continued on next page) ▶

◀ Qualifiers (continued)

Parameter Qualifiers [4.6]

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 parameter passed into a function
out	For values passed out of a function
inout	Function parameters passed in and out

Precision and Precision Qualifiers [4.7]

Example of precision qualifiers:

```
lowp float color;
out mediump vec2 P;
lowp ivec2 foo(lowp mat3);
highp mat4 m;
```

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

```
precision mediump int;
precision lowp sampler2D;
precision highp atomic_uint;
```

Invariant Qualifiers Examples [4.8.1]

```
invariant gl_Position;  // make built-in gl_Position be invariant
invariant centroid out vec3 Color;
```

To force all output variables to be invariant:

```
#pragma STDGL invariant(all)
```

Memory Access Qualifiers [4.10]

coherent	Reads and writes are coherent with other shader invocations
volatile	Underyling value can change at any time
restrict	A variable that is the exclusive way to access a value
readonly	Read only
writeonly	Write only

Matching Qualifiers [9.2]

The following tables summarize the requirements for matching of qualifiers, which apply whenever there are two or more matching variables in a shader interface. Errors are generated for conflicts.

- Yes or No pertains to whether the qualifiers must match.
- Consistent means qualifiers may be missing from a subset of declarations but they cannot conflict.
- The rules apply to all declared variables, irrespective of whether they are statically used, with the exception of inputs and outputs when shaders are linked [see 9.1].

Linked Shaders [9.2.1]

Qualifier Class	Qualifier	in/out	Default Uniforms	uniform Block	buffer Block
Storage	**in, out, uniform**	N/A	N/A	N/A	N/A
Auxiliary	**centroid, sample**	No	N/A	N/A	N/A
	patch	Yes	N/A	N/A	N/A
Layout	**location**	Yes	Consistent	N/A	N/A
	Block layout	N/A	N/A	Yes	Yes
	binding	N/A	Yes	Yes	Yes
	offset	N/A	Yes	N/A	N/A
	format	N/A	Yes	N/A	N/A
Interpolation	**smooth, flat**	Yes	N/A	N/A	N/A
Precision	**lowp, mediump highp**	No	Yes	No (TBD Yes?)	No (TBD Yes?)
Variance	**invariant, precise**	No	N/A	N/A	N/A
Memory	all	N/A	Yes	Yes	Yes

Separable Programs [9.2.2]

Qualifier Class	Qualifier	in/out
Storage	**in, out, uniform**	N/A
Auxiliary	**centroid, sample**	No
	patch	Yes
Layout	**location**	Yes
	Block layout	N/A
	binding	N/A
	offset	N/A
	format	N/A

Qualifier Class	Qualifier	in/out
Interpolation	**smooth, flat**	Yes
Precision	**lowp, mediump highp**	Yes
Variance	**invariant, precise**	No
Memory	all	N/A

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.)	R - L
16.	= += -= *= /= %= <<= >>= &= ^= |=	assignment arithmetic assignments	R - L
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

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
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;
```

Statements and Structure

Iteration and Jumps [6.3, 6.4]

Entry	void main()

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

Selection	if ( ) { }
	if ( ) { } else { }
	switch ( ) { case: break; default: }

Jump	break, continue, return discard // Fragment shader only

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 [7.1.1]

```
in  highp  int  gl_VertexID;
in  highp  int  gl_InstanceID;

out gl_PerVertex
{
      out  highp  vec4  gl_Position;
      out  highp  float  gl_PointSize;
};
```

Tessellation Control Shader Special Variables [7.1.2]

```
in  gl_PerVertex
{
      highp  vec4  gl_Position;
} gl_in [gl_MaxPatchVertices];

in  highp  int  gl_PatchVerticesIn;
in  highp  int  gl_PrimitiveID;
in  highp  int  gl_InvocationID;

out gl_PerVertex
{
      highp  vec4  gl_Position;
} gl_out[];

patch  out  highp  float  gl_TessLevelOuter[4];
patch  out  highp  float  gl_TessLevelInner[2];
patch  out  highp  vec4  gl_BoundingBox[2];
```

(Continued on next page) ▶

◀ Inputs, Outputs, Constants (continued)

Tessellation Eval. Shader Special Variables [7.1.3]

```
in gl_PerVertex
{
    highp  vec4  gl_Position;
} gl_in [gl_MaxPatchVertices];

in  highp  int  gl_PatchVerticesIn;
in  highp  int  gl_PrimitiveID;
in  highp  vec3  gl_TessCoord;
patch in  highp  float  gl_TessLevelOuter[4];
patch in  highp  float  gl_TessLevelInner[2];

out  gl_PerVertex
{
    highp  vec4  gl_Position;
};
```

Geometry Shader Special Variables [7.1.4]

```
in  gl_PerVertex
{
    highp  vec4  gl_Position;
} gl_in[];

in  highp  int  gl_PrimitiveIDIn;
in  highp  int  gl_InvocationID;

out  gl_PerVertex
{
    highp  vec4  gl_Position;
};

out  highp  int  gl_PrimitiveID;
out  highp  int  gl_Layer;
```

Fragment Shader Special Variables [7.1.5]

```
in   highp     vec4   gl_FragCoord;
in             bool   gl_FrontFacing;
out  highp     float  gl_FragDepth;
in   mediump   vec2   gl_PointCoord;
in             bool   gl_HelperInvocation;
in   highp     int    gl_PrimitiveID;
in   highp     int    gl_Layer;
in   lowp      int    gl_SampleID;
in   mediump   vec2   gl_SamplePosition;
in   highp     int    gl_SampleMaskIn[(gl_MaxSamples+31)/32];
out  highp     int    gl_SampleMask[(gl_MaxSamples+31)/32];
```

Compute Shader Special Variables [7.1.6]

Work group dimensions:

```
in     uvec3  gl_NumWorkGroups;
const  uvec3  gl_WorkGroupSize;
```

Work group and invocation IDs:

```
in     uvec3  gl_WorkGroupID;
in     uvec3  gl_LocalInvocationID;
```

Derived variables

```
in     uvec3  gl_GlobalInvocationID;
in     uint   gl_LocalInvocationIndex;
```

Built-In Constants With Minimum Values [7.2]

The following built-in constants are provided to all shaders. These variables are const-qualified.

Built-in Constant	Min.
mediump int gl_MaxAtomicCounterBindings	1
mediump int gl_MaxAtomicCounterBufferSize	32
mediump int gl_MaxCombinedAtomicCounterBuffers	1
mediump int gl_MaxCombinedAtomicCounters	8
mediump int gl_MaxCombinedImageUniforms	4
mediump int gl_MaxCombinedShaderOutputResources	4
mediump int gl_MaxCombinedTextureImageUnits	96
mediump int gl_MaxComputeAtomicCounterBuffers	1
mediump int gl_MaxComputeAtomicCounters	8
mediump int gl_MaxComputeImageUniforms	4
mediump int gl_MaxComputeTextureImageUnits	16
mediump int gl_MaxComputeUniformComponents	512
highp ivec3 gl_MaxComputeWorkGroupCount = ivec3(65535, 65535, 65535);	
highp ivec3 gl_MaxComputeWorkGroupSize = ivec3(128, 128, 64);	
mediump int gl_MaxDrawBuffers	4
mediump int gl_MaxFragmentAtomicCounterBuffers	0
mediump int gl_MaxFragmentAtomicCounters	0
mediump int gl_MaxFragmentImageUniforms	0
mediump int gl_MaxFragmentInputVectors	15
mediump int gl_MaxFragmentUniformVectors	224
mediump int gl_MaxGeometryAtomicCounterBuffers	0
mediump int gl_MaxGeometryAtomicCounters	0
mediump int gl_MaxGeometryImageUniforms	0
mediump int gl_MaxGeometryInputComponents	64
mediump int gl_MaxGeometryOutputComponents	64
mediump int gl_MaxGeometryOutputVertices	256
mediump int gl_MaxGeometryTextureImageUnits	16
mediump int gl_MaxGeometryTotalOutputComponents	1024
mediump int gl_MaxGeometryUniformComponents	1024
mediump int gl_MaxImageUnits	4
mediump int gl_MaxPatchVertices	32
mediump int gl_MaxProgramTexelOffset	7

Built-in Constant	Min.
mediump int gl_MaxSamples	4
mediump int gl_MaxTessControlAtomicCounters	0
mediump int gl_MaxTessControlAtomicCountersBuffers	0
mediump int gl_MaxTessControlImageUniforms	0
mediump int gl_MaxTessControlInputComponents	64
mediump int gl_MaxTessControlOutputComponents	64
mediump int gl_MaxTessControlTextureImageUnits	16
mediump int gl_MaxTessControlTotalOutputComponents	4096
mediump int gl_MaxTessControlUniformComponents	1024
mediump int gl_MaxTessEvaluationAtomicCounters	0
mediump int gl_MaxTessEvaluationAtomicCountersBuffers	0
mediump int gl_MaxTessEvaluationImageUniforms	0
mediump int gl_MaxTessEvaluationInputComponents	64
mediump int gl_MaxTessEvaluationOutputComponents	64
mediump int gl_MaxTessEvaluationTextureImageUnits	16
mediump int gl_MaxTessEvaluationUniformComponents	1024
mediump int gl_MaxTessGenLevel	64
mediump int gl_MaxTessPatchComponents	120
mediump int gl_MaxTextureImageUnits	16
mediump int gl_MaxVertexAtomicCounterBuffers	0
mediump int gl_MaxVertexAtomicCounters	0
mediump int gl_MaxVertexAttribs	16
mediump int gl_MaxVertexImageUniforms	0
mediump int gl_MaxVertexOutputVectors	16
mediump int gl_MaxVertexTextureImageUnits	16
mediump int gl_MaxVertexUniformVectors	256
mediump int gl_MinProgramTexelOffset	-8

Built-In Uniform State [7.3]

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

```
struct gl_DepthRangeParameters {
    highp  float  near;    // n
    highp  float  far;     // f
    highp  float  diff;    // f - n
};
uniform gl_DepthRangeParameters  gl_DepthRange;
uniform  lowp  int  gl_NumSamples;
```

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
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

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

(Continued on next page) ▶

◀ Inputs, Oututs, Constants (continued)

Common Functions (continued)

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*); Ti **mix**(Ti *x*, Ti *y*, Tb *a*); Tu **mix**(Tu *x*, Tu *y*, Tb *a*); Tb **mix**(Tb *x*, Tb *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
T **fma**(T *a*, T *b*, T *c*);	Computes and returns a * b + c
highp T **frexp**(highp T *x*, out highp Ti *exp*);	Splits each single-precision floating point number
highp T **ldexp**(highp T *x*, in highp Ti *exp*);	Builds a single-precision floating point number

Floating-Point Pack and Unpack Functions [8.4]

highp uint **packSnorm2x16**(vec2 *v*); highp uint **packUnorm2x16**(vec2 *v*);	Convert two floats to fixed point and pack into an integer
highp uint **packSnorm4x8**(mediump vec4 *v*); highp uint **packUnorm4x8**(mediump vec4 *v*);	Convert four floats to fixed point and pack into an integer
highp vec2 **unpackSnorm2x16**(highp uint *p*); highp vec2 **unpackUnorm2x16**(highp uint *p*);	Unpack fixed point value pair into floats
mediump vec4 **unpackSnorm4x8**(highp uint *p*); mediump vec4 **unpackUnorm4x8**(highp uint *p*);	Unpack fixed point values into floats
highp uint **packHalf2x16**(mediump vec2 *v*);	Convert two floats into half-precision floats and pack into an integer
mediump vec2 **unpackHalf2x16**(highp 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
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

Matrix Functions (continued)

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*

Integer Functions [8.8]

Ti **bitfieldExtract**(Ti *value*, int *offset*, int *bits*); Tu **bitfieldExtract**(Tu *value*, int *offset*, int *bits*);	Extracts bits, returning them in the least significant bits of corresponding component of the result
Ti **bitfieldInsert**(Ti *base*, Ti *insert*, int *offset*, int *bits*); Tu **bitfieldInsert**(Tu *base*, Tu *insert*, int *offset*, int *bits*);	Inserts bits into the corresponding component of base
highp Ti **bitfieldReverse**(highp Ti *value*); highp Tu **bitfieldReverse**(highp Tu *value*);	Reverses the bits of *value*
lowp Ti **bitCount**(Ti *value*); lowp Ti **bitCount**(Tu *value*);	Returns number of one bits in *value*
lowp Ti **findLSB**(Ti *value*); lowp Ti **findLSB**(Tu *value*);	Returns the bit number of the least significant one bit
lowp Ti **findMSB**(highp Ti *value*); lowp Ti **findMSB**(highp Tu *value*);	Returns the bit number of the most significant one bit
highp Tu **uaddCarry**(highp Tu *x*, highp Tu *y*, out lowp Tu *carry*);	Adds 32-bit integer or vector *y* to *x*
highp Tu **usubBorrow**(highp Tu *x*, highp Tu y, out lowp Tu *borrow*);	Subtracts 32-bit unsigned integer or vector *y* from *x*
void **umulExtended**(highp Tu *x*, highp Tu *y*, out highp Tu *msb*, out highp Tu *lsb*); void **imulExtended**(highp Ti *x*, highp Ti *y*, out highp Ti *msb*, out highp Ti *lsb*);	Multiply 32-bit integers or vectors to produce a 64-bit result

Texture Query Functions [8.9.1]

The function textureSize returns the dimensions of level *lod* for the texture bound to sampler, as described in [11.1.3.4] of the OpenGL ES 3.1 specification, under "Texture Queries". The initial "g" in a type name is a placeholder for nothing, "i", or "u".

highp ivec2	**textureSize**(gsampler2D *sampler*, int *lod*);
highp ivec3	**textureSize**(gsampler3D *sampler*, int *lod*);
highp ivec2	**textureSize**(gsamplerCube *sampler*, int *lod*);
highp ivec2	**textureSize**(gsampler2DMS *sampler*);
highp ivec3	**textureSize**(gsampler2DArray *sampler*, int *lod*);
highp ivec2	**textureSize**(samplerCubeShadow *sampler*, int *lod*);
highp ivec2	**textureSize**(sampler2DShadow *sampler*, int *lod*);
highp ivec3	**textureSize**(sampler2DArrayShadow *sampler*, int *lod*);
highp int	**textureSize**(gsamplerBuffer *sampler*);
highp ivec3	**textureSize**(samplerCubeArray *sampler*, int *lod*);
highp ivec3	**textureSize**(samplerCubeArrayShadow *sampler*, int *lod*);
highp ivec3	**textureSize**(sampler2DMSArray *sampler*);

Texel Lookup Functions [8.9.2]

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*]);
gvec4	**texture**(gsampler2DArray *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(sampler2DShadow *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(samplerCubeShadow *sampler*, vec4 *P* [, float *bias*]);
float	**texture**(sampler2DArrayShadow *sampler*, vec4 *P*);
gvec4	**texture**(gsamplerCubeArray *sampler*, vec4 *P* [, float *bias*]);
float	**texture**(samplerCubeArrayShadow *sampler*, vec4 *P*, float *compare*);
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	**textureLod**(gsamplerCubeArray *sampler*, vec4 *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	**texelFetch**(gsampler2DMS *sampler*, ivec2 *P*, int *sample*);
gvec4	**texelFetch**(gsamplerBuffer *sampler*, int *P*);
gvec4	**texelFetch**(gsampler2DMSArray *sampler*, ivec3 *P*, int *sample*);
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	**texture**(gsampler{2,3}D *sampler*, vec{2,3} *P* [, float *bias*]);
gvec4	**texture**(gsamplerCube *sampler*, vec3 *P* [, float *bias*]);
gvec4	**texture**(gsampler2DArray *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(sampler2DShadow *sampler*, vec3 *P* [, float *bias*]);
float	**texture**(samplerCubeShadow *sampler*, vec4 *P* [, float *bias*]);
float	**texture**(sampler2DArrayShadow *sampler*, vec4 *P*);
gvec4	**texture**(gsamplerCubeArray *sampler*, vec4 *P* [, float *bias*]);
float	**texture**(samplerCubeArrayShadow *sampler*, vec4 *P*, float *compare*);
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	**textureLod**(gsamplerCubeArray *sampler*, vec4 *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	**texelFetch**(gsampler2DMS *sampler*, ivec2 *P*, int *sample*);
gvec4	**texelFetch**(gsamplerBuffer *sampler*, int *P*);
gvec4	**texelFetch**(gsampler2DMSArray *sampler*, ivec3 *P*, int *sample*);

(Continued on next page) ▶

◀Built-In Functions (continued)

Texel Lookup Functions (continued)

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*);
gvec4 **textureGrad**(gsampler2DArray *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*);
float **textureGrad**(sampler2DShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*);
float **textureGrad**(samplerCubeShadow *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*);
float **textureGrad**(sampler2DArrayShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*);
gvec4 **textureGrad**(gsamplerCubeArray *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *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*);
gvec4 **textureGradOffset**(gsampler2DArray *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*);
float **textureGradOffset**(sampler2DShadow *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*);

Texture Gather Functions [8.9.3]

Texture gather functions take components of a single floating-point vector operand as a texture coordinate and return one component from each texel in a four-component result vector.

gvec4 **textureGather**(gsampler2D *sampler*, vec2 *P*[, int *comp*]);
gvec4 **textureGather**(gsampler2DArray *sampler*, vec3 *P*[, int *comp*]);
gvec4 **textureGather**(gsamplerCube *sampler*, vec3 *P*[, int *comp*]);
vec4 **textureGather**(sampler2DShadow *sampler*, vec2 *P*, float *refZ*);
vec4 **textureGather**(sampler2DArrayShadow *sampler*, vec3 *P*, float *refZ*);
vec4 **textureGather**(samplerCubeShadow *sampler*, vec3 *P*, float *refZ*);
gvec4 **textureGather**(gsamplerCubeArray *sampler*, vec4 *P*[, int *comp*]);
vec4 **textureGather**(samplerCubeArrayShadow *sampler*, vec4 *P*, float *refZ*);

Texture Gather Functions (continued)

gvec4 **textureGatherOffset**(gsampler2D *sampler*, vec2 *P*, ivec2 *offset*[, int *comp*]);
gvec4 **textureGatherOffset**(gsampler2DArray *sampler*, vec3 *P*, ivec2 *offset*[, int *comp*]);
vec4 **textureGatherOffset**(sampler2DShadow *sampler*, vec2 *P*, float *refZ*, ivec2 *offset*);
vec4 **textureGatherOffset**(sampler2DArrayShadow *sampler*, vec3 *P*, float *refZ*, ivec2 *offset*);
gvec4 **textureGatherOffsets**(gsampler2D *sampler*, vec2 *P*, ivec2 *offsets[4]* [, int *comp*]);
gvec4 **textureGatherOffsets**(gsampler2DArray *sampler*, vec3 *P*, ivec2 *offsets[4]* [, int *comp*]);
vec4 **textureGatherOffsets**(sampler2DShadow *sampler*, vec2 *P*, float *refZ*, ivec2 *offsets[4]*);
vec4 **textureGatherOffsets**(sampler2DArrayShadow *sampler*, vec3 *P*, float *refZ*, ivec2 *offsets[4]*);

Atomic-Counter Functions [8.10]

Returns the value of an atomic counter.

uint **atomicCounterIncrement**(atomic_uint *c*);	Increments the counter and returns its value prior to the increment
uint **atomicCounterDecrement**(atomic_uint *c*);	Decrements the counter and returns its value prior to the decrement
uint **atomicCounter**(atomic_uint *c*);	Returns counter value

Atomic Memory Functions [8.11]

Atomic memory functions perform atomic operations on an individual signed or unsigned integer stored in buffer-object or shared-variable storage.

uint **atomicAdd**(inout uint *mem*, uint *data*); int **atomicAdd**(inout int *mem*, int *data*);	Adds the value of *data* to *mem*
uint **atomicMin**(inout uint *mem*, uint *data*); int **atomicMin**(inout int *mem*, int *data*);	Minimum of value of *data* and *mem*
uint **atomicMax**(inout uint *mem*, uint *data*); int **atomicMax**(inout int *mem*, int *data*);	Maximum of value of *data* and *mem*
uint **atomicAnd**(inout uint *mem*, uint *data*); int **atomicAnd**(inout int *mem*, int *data*);	Bit-wise AND of value of *data* and *mem*
uint **atomicOr**(inout uint *mem*, uint *data*); int **atomicOr**(inout int *mem*, int *data*);	Bit-wise OR of value of *data* and *mem*
uint **atomicXor**(coherent inout uint *mem*, uint *data*); int **atomicXor**(coherent inout int *mem*, int *data*);	Bit-wise XOR of value of *data* and *mem*
uint **atomicExchange**(coherent inout uint *mem*, uint *data*); int **atomicExchange**(coherent inout int *mem*, int *data*);	Copy the value of *data*
uint **atomicCompSwap**(coherent inout uint *mem*, uint *compare*, uint *data*); int **atomicCompSwap**(coherent inout int *mem*, int *compare*, int *data*);	Compares *compare* and the contents of *mem*. If equal, returns *data*; else *mem*

Image Functions [8.12]

Image functions read and write individual texels of a texture. Each image variable references an image unit, which has a texture image attached. Type gvec is ivec or uvec. The placeholder gimage may be image, iimage, or uimage.

The *IMAGE_PARAMS* placeholder is replaced by one of the following parameter lists:

gimage2D *image*, ivec2 *P*
gimage3D *image*, ivec3 *P*
gimageCube *image*, ivec3 *P*
gimage2DArray *image*, ivec3 *P*
gimageBuffer *image*, int *P*
gimageCubeArray *image*, ivec3 *P*

highp ivec2 **imageSize**(readonly writeonly gimage2D *image*);
highp ivec3 **imageSize**(readonly writeonly gimage3D *image*);
highp ivec2 **imageSize**(readonly writeonly gimageCube *image*);
highp ivec3 **imageSize**(readonly writeonly gimage2DArray *image*);
highp int **imageSize**(readonly writeonly gimageBuffer *image*);
highp ivec3 **imageSize**(readonly writeonly gimageCubeArray *image*);

highp gvec4 **imageLoad**(readonly *IMAGE_PARAMS*);

void **imageStore**(writeonly *IMAGE_PARAMS*, gvec4 *data*);

Image Functions (continued)

highp uint **imageAtomicAdd**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicAdd**(*IMAGE_PARAMS*, int *data*);

highp uint **imageAtomicMin**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicMin**(*IMAGE_PARAMS*, int *data*);

highp uint **imageAtomicMax**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicMax**(*IMAGE_PARAMS*, int *data*);

highp uint **imageAtomicAnd**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicAnd**(*IMAGE_PARAMS*, int *data*);

highp uint **imageAtomicOr**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicOr**(*IMAGE_PARAMS*, int *data*);

highp uint **imageAtomicXor**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicXor**(*IMAGE_PARAMS*, int *data*);

highp uint **imageAtomicExchange**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicExchange**(*IMAGE_PARAMS*, int *data*);
highp float **imageAtomicExchange**(*IMAGE_PARAMS*, int *float*);

highp uint **imageAtomicCompSwap**(*IMAGE_PARAMS*, uint *data*);
highp int **imageAtomicCompSwap**(*IMAGE_PARAMS*, int *data*);

Geometry Shader Functions [8.13]

Approximated using local differencing.

void **EmitVertex**( );	Emits current values of output variables to the current output primitive
void **EndPrimitive**( );	Completes the current output primitive and starts a new one

Fragment Processing Functions [8.14]

Available only in fragment shaders.

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

Interpolation Functions [8.14.1]

Compute an interpolated value of a fragment shader input variable at a shader-specified (x,y) location.

float **interpolateAtCentroid**(float *interpolant*);
vec2 **interpolateAtCentroid**(vec2 *interpolant*);
vec3 **interpolateAtCentroid**(vec3 *interpolant*);
vec4 **interpolateAtCentroid**(vec4 *interpolant*);

float **interpolateAtSample**(float *interpolant,* int *sample*);
vec2 **interpolateAtSample**(vec2 *interpolant,* int *sample*);
vec3 **interpolateAtSample**(vec3 *interpolant,* int *sample*);
vec4 **interpolateAtSample**(vec4 *interpolant,* int *sample*);

float **interpolateAtOffset**(float *interpolant,* vec2 *offset*);
vec2 **interpolateAtOffset**(vec2 *interpolant,* vec2 *offset*);
vec3 **interpolateAtOffset**(vec3 *interpolant,* vec2 *offset*);
vec4 **interpolateAtOffset**(vec4 *interpolant,* vec2 *offset*);

Shader Invocation Control Function [8.15]

The shader invocation control function controls the relative execution order of multiple shader invocations.

void **barrier**();	All invocations for a single work group must enter **barrier**() before any will continue beyond it

Shader Memory Control Functions [8.16]

Shader memory control functions control the ordering of memory transactions issued by or within a single shader invocation.

void **memoryBarrier**();	Control the ordering of memory transactions
void **memoryBarrierAtomicCounter**();	Control the ordering of accesses to atomic counter variables
void **memoryBarrierBuffer**();	Control the ordering of memory transactions to buffer variables
void **memoryBarrierImage**();	Control the ordering of memory transactions to images
void **memoryBarrierShared**();	Control the ordering of memory transactions to shared variables. Available only in compute shaders.
void **groupMemoryBarrier**();	Control the ordering of all memory transactions. Available only in compute shaders.

OpenGL ES API and OpenGL Shading Language Reference Guide Index

The following index shows each item included in this reference guide, along with the page on which it is described. The color of the row in the table below is the color of the pane to which you should refer.

Notes