OpenGL 4.1 API Quick Reference Card - Page 1

OpenGL® is the only cross-platform graphics API that enables developers of software for PC, workstation, and supercomputing hardware to create high-performance, visually-compelling graphics software applications, in markets such as CAD, content creation, energy, entertainment, game development, manufacturing, medical, and virtual reality.
Specifications are available at www.opengl.org/registry

- *see FunctionName* refers to functions on this reference card.
- Content shown in blue is removed from the OpenGL 4.1 core profile and present only in the OpenGL 4.1 compatibility profile. Profile selection is made at context creation.
- **[n.n.n]** and **[Table n.n]** refer to sections and tables in the OpenGL 4.1 core specification.
- **[n.n.n]** and **[Table n.n]** refer to sections and tables in the OpenGL 4.1 compatibility profile specification, and are shown only when they differ from the core profile.
- **[n.n.n]** refers to sections in the OpenGL Shading Language 4.10 specification.

OpenGL Command Syntax [2.3]

GL commands are formed from a return type, a name, and optionally up to 4 characters (or character pairs) from the Command Letters table (above), as shown by the prototype:

return-type **Name**{1234}{b s i i64 f d ub us ui ui64}{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, or else corresponds to the type letters from the Command Table (above). If "v" is present, an array of N items are 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

OpenGL Operation

Floating-Point Numbers [2.1.1 - 2.1.2]

16-Bit	1-bit sign, 5-bit exponent, 10-bit mantissa
Unsigned 11-Bit	no sign bit, 5-bit exponent, 6-bit mantissa
Unsigned 10-Bit	no sign bit, 5-bit exponent, 5-bit mantissa

Command Letters [Table 2.1]

Letters are used in commands to denote types.

b -	byte (8 bits)	**ub** -	ubyte (8 bits)
s -	short (16 bits)	**us** -	ushort (16 bits)
i -	int (32 bits)	**ui** -	uint (32 bits)
i64 -	int64 (64 bits)	**ui64** -	uint64 (64 bits)
f -	float (32 bits)	**d** -	double (64 bits)

OpenGL Errors [2.5]

enum **GetError**(void); Returns the numeric error code.

Vertex Arrays [2.8]

void **VertexPointer**(int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: SHORT, INT, FLOAT, HALF_FLOAT, DOUBLE, {UNSIGNED_}INT_2_10_10_10_REV
void **NormalPointer**(enum *type*, sizei *stride*, const void **pointer*);
type: see VertexPointer, plus BYTE
void **ColorPointer**(int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: see VertexPointer, plus BYTE, UINT, UNSIGNED_{BYTE, SHORT}
void **SecondaryColorPointer**(int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: see ColorPointer
void **IndexPointer**(enum *type*, sizei *stride*, const void **pointer*);
type: UNSIGNED_BYTE, SHORT, INT, FLOAT, DOUBLE
void **EdgeFlagPointer**(sizei *stride*, const void **pointer*);
void **FogCoordPointer**(enum *type*, sizei *stride*, const void **pointer*);
type: FLOAT, HALF_FLOAT, DOUBLE
void **TexCoordPointer**(int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: see VertexPointer
void **VertexAttribPointer**(uint *index*, int *size*, enum *type*, boolean *normalized*, sizei *stride*, const void **pointer*);
type: see ColorPointer, plus FIXED
void **VertexAttribIPointer**(uint *index*, int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: BYTE, SHORT, UNSIGNED_{BYTE, SHORT}, INT, UINT
index: [0, MAX_VERTEX_ATTRIBS - 1]
void **VertexAttribLPointer**(uint *index*, int *size*, enum *type*, sizei *stride*, const void **pointer*);
type: DOUBLE
index: see VertexAttribIPointer
void **EnableClientState**(enum *array*);
void **DisableClientState**(enum *array*);
array: {VERTEX, NORMAL, COLOR, INDEX}_ARRAY, {SECONDARY_COLOR, EDGE_FLAG}_ARRAY, FOG_COORD_ARRAY, TEXTURE_COORD_ARRAY
void **EnableVertexAttribArray**(uint *index*);
void **DisableVertexAttribArray**(uint *index*);
index: [0, MAX_VERTEX_ATTRIBS - 1]
void **VertexAttribDivisor**(uint *index*, uint *divisor*);
void **ClientActiveTexture**(enum *texture*);
index: TEXTURE*i* (where *i* is [0, MAX_TEXTURE_COORDS - 1])
void **ArrayElement**(int *i*);
Enable/Disable(PRIMITIVE_RESTART)
void **PrimitiveRestartIndex**(uint *index*);

Drawing Commands [2.8.3] [2.8.2]

void **DrawArrays**(enum *mode*, int *first*, sizei *count*);
void **DrawArraysInstanced**(enum *mode*, int *first*, sizei *count*, sizei *primcount*);
void **DrawArraysIndirect**(enum *mode*, const void **indirect*);
void **MultiDrawArrays**(enum *mode*, const int **first*, sizei **count*, const sizei *primcount*);
void **DrawElements**(enum *mode*, sizei *count*, enum *type*, const void **indices*);
void **DrawElementsInstanced**(enum *mode*, sizei *count*, enum *type*, const void **indices*, sizei *primcount*);
void **MultiDrawElements**(enum *mode*, sizei **count*, enum *type*, const void ***indices*, sizei *primcount*);
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 *primcount*, int *basevertex*);
void **DrawElementsIndirect**(enum *mode*, enum *type*, const void **indirect*);
void **MultiDrawElementsBaseVertex**(enum *mode*, sizei **count*, enum *type*, const void ***indices*, sizei *primcount*, int **basevertex*);
mode: POINTS, LINE_STRIP, LINE_LOOP, LINES, POLYGON, TRIANGLE_{STRIP, FAN}, TRIANGLES, QUAD_STRIP, QUADS, LINES_ADJACENCY, {LINE, TRIANGLE}_STRIP_ADJACENCY, PATCHES, TRIANGLES_ADJACENCY,
type: UNSIGNED_{BYTE, SHORT, INT}
void **InterleavedArrays**(enum *format*, sizei *stride*, const void **pointer*);
format: V2F, V3F, C4UB_{V2F, V3F}, {C3F, N3F}_V3F, C4F_N3F_V3F, T2F_{C4UB, C3F, N3F}_V3F, T2F_V3F, T4F_V4F, T2F_C4F_N3F_{V3F, V4F}

Buffer Objects [2.9]

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

Creating and Binding Buffer Objects [2.9.1]

void **BindBuffer**(enum *target*, uint *buffer*);
target: PIXEL_{PACK, UNPACK}_BUFFER, UNIFORM_BUFFER ARRAY_BUFFER, COPY_{READ, WRITE}_BUFFER, DRAW_INDIRECT_BUFFER, ELEMENT_ARRAY_BUFFER, TEXTURE_BUFFER, TRANSFORM_FEEDBACK_BUFFER,
void **BindBufferRange**(enum *target*, uint *index*, uint *buffer*, intptr *offset*, sizeiptr *size*);
target: {TRANSFORM_FEEDBACK, UNIFORM}_BUFFER
void **BindBufferBase**(enum *target*, uint *index*, uint *buffer*);
target: see BindBufferRange

Creating Buffer Object Data Stores [2.9.2]

void **BufferData**(enum *target*, sizeiptr *size*, const void **data*, enum *usage*);
usage: STREAM_{DRAW, READ, COPY}, {DYNAMIC, STATIC}_{DRAW, READ, COPY}
target: see BindBuffer
void **BufferSubData**(enum *target*, intptr *offset*, sizeiptr *size*, const void **data*);
target: see BindBuffer

Vertex Specification

Begin and End [2.6]

Enclose coordinate sets between Begin/End pairs to construct geometric objects.
void **Begin**(enum *mode*);
void **End**(void);
mode: see MultiDrawElementsBaseVertex

Separate Patches

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

Polygon Edges [2.6.2]

Flag each edge of polygon primitives as either boundary or non-boundary.
void **EdgeFlag**(boolean *flag*);
void **EdgeFlagv**(const boolean **flag*);

Vertex Specification [2.7]

Vertices have 2, 3, or 4 coordinates, and optionally a current normal, multiple current texture coordinate sets, multiple current generic vertex attributes, current color, current secondary color, and current fog coordinates.
void **Vertex{234}{sifd}**(T *coords*);
void **Vertex{234}{sifd}v**(const T *coords*);
void **VertexP{234}ui**(enum *type*, uint *coords*);
void **VertexP{234}uiv**(enum *type*, const uint **coords*);
type: INT_2_10_10_10_REV, UNSIGNED_INT_2_10_10_10_REV
void **TexCoord{1234}{sifd}**(T *coords*);
void **TexCoord{1234}{sifd}v**(const T *coords*);
void **TexCoordP{1234}ui**(enum *type*, uint *coords*);
void **TexCoordP{1234}uiv**(enum *type*, const uint **coords*);
type: see VertexP{234}uiv
void **MultiTexCoord{1234}{sifd}**(enum *texture*, T *coords*);
void **MultiTexCoord{1234}{sifd}v**(enum *texture*, const T *coords*);
texture: TEXTURE*i* (where *i* is [0, MAX_TEXTURE_COORDS - 1])
void **MultiTexCoordP{1234}ui**(enum *texture*, enum *type*, uint *coords*);
void **MultiTexCoordP{1234}uiv**(enum *texture*, enum *type*, const uint **coords*);
void **Normal3{bsifd}**(const T *coords*);
void **Normal3{bsifd}v**(T *coords*);
void **NormalP3ui**(enum *type*, uint *normal*);
void **NormalP3uiv**(enum *type*, uint **normal*);
void **FogCoord{fd}**(T *coord*);
void **FogCoord{fd}v**(const T *coord*);
void **Color{34}{bsifd ubusui}**(T *components*);
void **Color{34}{bsifd ubusui}v**(const T *components*);
void **ColorP{34}ui**(enum *type*, uint *coords*);
void **ColorP{34}uiv**(enum *type*, const uint **coords*);
void **SecondaryColor3{bsifd ubusui}**(T *components*);
void **SecondaryColor3{bsifd ubusui}v**(const T *components*);
void **SecondaryColorP3ui**(enum *type*, uint *coords*);
void **SecondaryColorP3uiv**(enum *type*, const uint **coords*);
void **Index{sifd ub}**(T *index*);
void **Index{sifd ub}v**(const T *index*);

The VertexAttrib* commands specify generic attributes with components of type float (VertexAttrib*), int or uint (VertexAttribI*), or double (VertexAttribL*d*).
void **VertexAttrib{1234}{sfd}**(uint *index*, T *values*);
void **VertexAttrib{123}{sfd}v**(uint *index*, const T *values*);
void **VertexAttrib4{bsifd ub us ui}v**(uint *index*, const T *values*);
void **VertexAttrib4Nub**(uint *index*, T *values*);
void **VertexAttrib4N{bsi ub us ui}v**(uint *index*, const T *values*);
void **VertexAttribI{1234}{i ui}**(uint *index*, T *values*);
void **VertexAttribI{1234}{i ui}v**(uint *index*, const T *values*);
void **VertexAttribI4{bs ub us}v**(uint *index*, const T *values*);
void **VertexAttribP{1234}ui**(uint *index*, enum *type*, boolean *normalized*, uint *value*)
void **VertexAttribL{1234}d**(uint *index*, T *values*);
void **VertexAttribL{1234}dv**(uint *index*, T *values*);
void **VertexAttribP{1234}uiv**(uint *index*, enum *type*, boolean *normalized*, const uint **value*);
type: see VertexP{234}uiv

Mapping/Unmapping Buffer Data [2.9.3]

void ***MapBufferRange**(enum *target*, intptr *offset*, sizeiptr *length*, bitfield *access*);
access: The logical OR of MAP_{READ, WRITE}_BIT, MAP_INVALIDATE_{BUFFER, RANGE}_BIT, MAP_{FLUSH_EXPLICIT, UNSYNCHRONIZED}_BIT,
target: see BindBuffer
void ***MapBuffer**(enum *target*, enum *access*);
access: READ_ONLY, WRITE_ONLY, READ_WRITE
void **FlushMappedBufferRange**(enum *target*, intptr *offset*, sizeiptr *length*);
target: see BindBuffer
boolean **UnmapBuffer**(enum *target*);
target: see BindBuffer

Copying Between Buffers [2.9.5]

void ***CopyBufferSubData**(enum *readtarget*, enum *writetarget*, intptr *readoffset*, intptr *writeoffset*, sizeiptr *size*);
readtarget and *writetarget: see BindBuffer*

Vertex Array Objects [2.10]

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*);

Buffer Object Queries [6.1.9] [6.1.15]

boolean **IsBuffer**(uint *buffer*);
void **GetBufferParameteriv**(enum *target*, enum *pname*, int **data*);
target: see BindBuffer
pname: BUFFER_SIZE, BUFFER_USAGE, BUFFER_ACCESS{_FLAGS}, BUFFER_MAPPED, BUFFER_MAP_{OFFSET, LENGTH}
void **GetBufferParameteri64v**(enum *target*, enum *pname*, int64 **data*);
target: see BindBuffer
pname: see GetBufferParameteriv,
void **GetBufferSubData**(enum *target*, intptr *offset*, sizeiptr *size*, void **data*);
target: see BindBuffer
void **GetBufferPointerv**(enum *target*, enum *pname*, void ***params*);
target: see BindBuffer
pname: BUFFER_MAP_POINTER

Vertex Array Object Queries [6.1.10] [6.1.16]

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

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Rectangles, Matrices, Texture Coordinates

Rectangles [2.11]

Specifiy rectangles as two corner vertices.

void **Rect{sifd}**(T *x1*, T *y1*, T *x2*, T *y2*);

void **Rect{sifd}v**(const T *v1*[2], const T *v2*[2]);

Matrices [2.12.1]

void **MatrixMode**(enum *mode*);
mode: TEXTURE, MODELVIEW, COLOR, PROJECTION

void **LoadMatrix{fd}**(const T *m*[16]);

void **MultMatrix{fd}**(const T *m*[16]);

void **LoadTransposeMatrix{fd}**(const T *m*[16]);

void **MultTransposeMatrix{fd}**(const T *m*[16]);

void **LoadIdentity**(void);

void **Rotate{fd}**(T *θ*, T *x*, T *y*, T *z*);

void **Translate{fd}**(T *x*, T *y*, T *z*);

void **Scale{fd}**(T *x*, T *y*, T *z*);

void **Frustum**(double *l*, double *r*, double *b*, double *t*, double *n*, double *f*);

void **Ortho**(double *l*, double *r*, double *b*, double *t*, double *n*, double *f*);

void **PushMatrix**(void);

void **PopMatrix**(void);

Texture Coordinates [2.12.3]

void **TexGen{ifd}**(enum *coord*, enum *pname*, T *param*);

void **TexGen{ifd}v**(enum *coord*, enum *pname*, const T *params*);
coord: S, T, R, Q
pname: TEXTURE_GEN_MODE, {OBJECT, EYE}_PLANE

Lighting and Color

Enable/Disable(LIGHTING) // generic enable
Enable/Disable(LIGHT*i*) // indiv. lights

Lighting Parameter Spec. [2.13.2]

void **Material{if}**(enum *face*, enum *pname*, T *param*);

void **Material{if}v**(enum *face*, enum *pname*, const T *params*);
face: FRONT, BACK, FRONT_AND_BACK
pname: AMBIENT, DIFFUSE, AMBIENT_AND_DIFFUSE, EMISSION, SHININESS, COLOR_INDEXES, SPECULAR

void **Light{if}**(enum *light*, enum *pname*, T *param*);

void **Light{if}v**(enum *light*, enum *pname*, const T *params*);
light: LIGHT*i* (where *i* >= 0)
pname: AMBIENT, DIFFUSE, SPECULAR, POSITION, SPOT_{DIRECTION, EXPONENT, CUTOFF}, {CONSTANT, LINEAR,QUADRATIC}_ATTENUATION

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

void **LightModel{if}v**(enum *pname*, const T *params*);
pname: LIGHT_MODEL_{AMBIENT, LOCAL_VIEWER}, LIGHT_MODEL_{TWO_SIDE, COLOR_CONTROL}

ColorMaterial [4.3.1] [2.13.3, 3.7.5]

Enable/Disable(COLOR_MATERIAL)

void **ColorMaterial**(enum *face*, enum *mode*);
face: FRONT, BACK, FRONT_AND_BACK
mode: EMISSION, AMBIENT, DIFFUSE, SPECULAR, AMBIENT_AND_DIFFUSE

void **ClampColor**(enum *target*, enum *clamp*);
target: CLAMP_VERTEX_COLOR
clamp: TRUE, FALSE, FIXED_ONLY

Flatshading [2.19] [2.22]

void **ProvokingVertex**(enum *provokeMode*);
provokeMode: {FIRST, LAST}_VERTEX_CONVENTION

void **ShadeModel**(enum *mode*);
mode: SMOOTH, FLAT

Queries [6.1.3]

void **GetLight{if}v**(enum *light*, enum *value*, T *data*);

void **GetMaterial{if}v**(enum *face*, enum *value*, T *data*);
face: FRONT, BACK

Shaders and Programs

Shader Objects [2.11.1-2] [2.14.1-2]

uint **CreateShader**(enum *type*);
type: {VERTEX, FRAGMENT, GEOMETRY}_SHADER, TESS_{EVALUATION, CONTROL}_SHADER

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

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

void **ReleaseShaderCompiler**(void);

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

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

Program Objects [2.11.3] [2.14.3]

uint **CreateProgram**(void);

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

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

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

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

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

void **ProgramParameteri**(uint *program*, enum *pname*, int *value*);
pname: PROGRAM_SEPARABLE, PROGRAM_BINARY_{RETRIEVABLE_HINT},
value: TRUE, FALSE

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

Program Pipeline Objects [2.11.4] [2.14.4]

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

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

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

void **UseProgramStages**(uint *pipeline*, bitfield *stages*, uint *program*);
stages: ALL_SHADER_BITS or the Bitwise OR of TESS_{CONTROL, EVALUATION}_SHADER_BIT, {VERTEX, GEOMETRY, FRAGMENT}_SHADER_BIT

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

Program Binaries [2.11.5] [2.14.5]

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 [2.11.6] [2.14.6]

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

void **GetActiveAttrib**(uint *program*, uint *index*, sizei *bufSize*, sizei **length*, int **size*, enum **type*, char **name*);
**type* returns: FLOAT, FLOAT_{VEC*n*, MAT*n*, MAT*n*x*m*}, INT, INT_VEC*n*, UNSIGNED_{INT, INT_VEC*n*}

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

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

Uniform Variables [2.11.7] [2.14.7]

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}, UNIFORM_BLOCK_NAME_{LENGTH, UNIFORM}, UNIFORM_BLOCK_ACTIVE_UNIFORMS_INDICES, UNIFORM_BLOCK_REFERENCED_BY_VERTEX_SHADER, UNIFORM_BLOCK_REFERENCED_BY_{FRAGMENT_SHADER, GEOMETRY_SHADER, TESS_CONTROL_SHADER, TESS_EVALUATION_SHADER}

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

void **GetActiveUniformName**(uint *program*, uint *uniformIndex*, sizei *bufSize*, sizei **length*, char **uniformName*);

void **GetActiveUniform**(uint *program*, uint *index*, sizei *bufSize*, sizei **length*, int **size*, enum **type*, char **name*);
**type* returns: DOUBLE, DOUBLE_{VEC*n*, MAT*n*, MAT*n*x*n*}, FLOAT, FLOAT_{VEC*n*, MAT*n*, MAT*n*x*n*}, INT, INT_VEC*n*, UNSIGNED_INT{_VEC*n*}, BOOL, BOOL_VEC*n*, and the SAMPLER_* and {UNSIGNED_}INT_SAMPLER_* values in [Table 2.13] [Table 2.16]

void **GetActiveUniformsiv**(uint *program*, sizei *uniformCount*, const uint **uniformIndices*, enum *pname*, int **params*);
pname: UNIFORM_{TYPE, SIZE, NAME_LENGTH}, UNIFORM_BLOCK_INDEX, UNIFORM_OFFSET, UNIFORM_{ARRAY, MATRIX}_STRIDE, UNIFORM_IS_ROW_MAJOR

Load Uniform Vars. In Default Uniform Block

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

void **Uniform{1234}{ifd}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}{fd}v**(int *location*, sizei *count*, boolean *transpose*, const T **value*);

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

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

void **ProgramUniform{1234}{ifd}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}{fd}v**(uint *program*, int *location*, sizei *count*, boolean *transpose*, const float **value*);

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

Uniform Buffer Object Bindings

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

Subroutine Uniform Variables [2.11.8] [2.14.8]

int **GetSubroutineUniformLocation**(uint *program*, enum *shadertype*, const char **name*);

uint **GetSubroutineIndex**(uint *program*, enum *shadertype*, const char **name*);

void **GetActiveSubroutineUniformiv**(uint *program*, enum *shadertype*, uint *index*, enum *pname*, int **values*);
pname: {NUM_}COMPATIBLE_SUBROUTINES, UNIFORM_SIZE, UNIFORM_NAME_LENGTH

void **GetActiveSubroutineUniformName**(uint *program*, enum *shadertype*, uint *index*, sizei *bufsize*, sizei **length*, char **name*);

void **GetActiveSubroutineName**(uint *program*, enum *shadertype*, uint *index*, sizei *bufsize*, sizei **length*, char **name*);

(Shaders and Programs Continue >)

Rendering Control & Queries

Asynchronous Queries [2.15] [2.18]

void **BeginQuery**(enum *target*, uint *id*);
target: PRIMITIVES_GENERATED{*n*}, {ANY_}SAMPLES_PASSED, TIME_ELAPSED, TRANSFORM_FEEDBACK_PRIMITIVES_WRITTEN{*n*}

void **EndQuery**(enum *target*);

void **BeginQueryIndexed**(enum *target*, uint *index*, uint *id*);

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

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

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

Conditional Rendering [2.16] [2.19]

void **BeginConditionalRender**(uint *id*, enum *mode*);
mode: QUERY_WAIT, QUERY_NO_WAIT, QUERY_BY_REGION_{WAIT, NO_WAIT}

void **EndConditionalRender**(void);

Transform Feedback [2.17] [2.20]

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);

void **DrawTransformFeedback**(enum *mode*, uint *id*);

void **DrawTransformFeedbackStream**(enum *mode*, uint *id*, uint *stream*);

Transform Feedback Query [6.1.11] [6.1.17]

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

Current Raster Position [2.25]

void **RasterPos{234}{sifd}**(T *coords*);

void **RasterPos{234}{sifd}v**(const T *coords*);

void **WindowPos{23}{sifd}**(T *coords*);

void **WindowPos{23}{sifd}v**(const T *coords*);

Asynchronous Queries [6.1.7] [6.1.13]

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

void **GetQueryiv**(enum *target*, enum *pname*, int **params*);
target: *see BeginQuery*, plus TIMESTAMP
pname: CURRENT_QUERY, QUERY_COUNTER_BITS

void **GetQueryIndexediv**(enum *target*, uint *index*, enum *pname*, int **params*);
target: *see BeginQuery*
pname: CURRENT_QUERY, QUERY_COUNTER_BITS

void **GetQueryObjectiv**(uint *id*, enum *pname*, int **params*);

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

void **GetQueryObjecti64v**(uint *id*, enum *pname*, int64 **params*);

void **GetQueryObjectui64v**(uint *id*, enum *pname*, uint64 **params*);
pname: QUERY_RESULT{_AVAILABLE}

Viewport and Clipping

Controlling Viewport [2.14.1] [2.17.1]

void **DepthRangeArrayv**(uint *first*, sizei *count*, const clampd **v*);

void **DepthRangeIndexed**(uint *index*, clampd *n*, clampd *f*);

void **DepthRange**(clampd *n*, clampd *f*);

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

void **ViewportArrayv**(uint *first*, sizei *count*, const float **v*);

void **ViewportIndexedf**(uint *index*, float *x*, float *y*, float *w*, float *h*);

void **ViewportIndexedfv**(uint *index*, const float **v*);

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

Clipping [2.20] [2.23, 6.1.3]

Enable/Disable(CLIP_DISTANCE*i*)
i: [0, MAX_CLIP_DISTANCES - 1]

void **ClipPlane**(enum *p*, const double *eqn*[4]);
p: CLIP_PLANE*i* (where *i* is [0, MAX_CLIP_PLANES - 1])

void **GetClipPlane**(enum *plane*, double *eqn*[4]);

Shaders and Programs (cont.)

void **UniformSubroutinesuiv**(enum *shadertype*, sizei *count*, const uint **indices*);

Varying Variables [2.11.10] [2.14.10]

void **TransformFeedbackVaryings**(uint *program*, sizei *count*, const char ***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, FLOAT{_VEC*n*}, DOUBLE{_VEC*n*}, {UNSIGNED_}INT, {UNSIGNED_}INT_VEC*n*, MAT*nxm*, {FLOAT, DOUBLE}_MAT*n*, {FLOAT, DOUBLE}_MAT*nxm*

Shader Execution [2.11.11] [2.14.11]

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

Tessellation Control Shaders [2.12.1] [2.15.1]

void **PatchParameterfv**(enum *pname*, const float **values*);
pname: PATCH_DEFAULT_{INNER, OUTER}_LEVEL

Fragment Shaders [3.9.2] [3.12.2]

void **BindFragDataLocation**(uint *program*, uint *colorNumber*, const char **name*);

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

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

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

Shader and Program Queries

Shader Queries [6.1.12] [6.1.18]

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

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

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, FRAGMENT}_SHADER
precisiontype: LOW_{FLOAT, INT}, MEDIUM_{FLOAT, INT}, HIGH_{FLOAT, INT}

void **GetProgramStageiv**(uint program, enum *shadertype*, enum *pname*, int **values*);
pname: ACTIVE_SUBROUTINES, ACTIVE_SUBROUTINE_{UNIFORMS, MAX_LENGTH}, ACTIVE_SUBROUTINE_UNIFORM_LOCATIONS, ACTIVE_SUBROUTINE_UNIFORM_MAX_LENGTH

Program Queries [6.1.12] [6.1.18]

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

void **GetVertexAttrib{d f i}v**(uint *index*, enum *pname*, T **params*);
pname: VERTEX_ATTRIB_ARRAY_BUFFER_BINDING, VERTEX_ATTRIB_ARRAY_ENABLED, VERTEX_ATTRIB_ARRAY_SIZE, VERTEX_ATTRIB_ARRAY_STRIDE, VERTEX_ATTRIB_ARRAY_TYPE, VERTEX_ATTRIB_ARRAY_NORMALIZED, VERTEX_ATTRIB_ARRAY_DIVISOR, VERTEX_ATTRIB_ARRAY_INTEGER, CURRENT_VERTEX_ATTRIB

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

void **GetVertexAttribLdv**(uint *index*, enum *pname*, double **params*);
pname: *see GetVertexAttrib{d f i}v*

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

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

void **GetUniformSubroutineuiv**(enum *shadertype*, int *location*, uint **params*);

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

void **GetProgramiv**(uint *program*, enum *pname*, int **params*);
pname: DELETE _STATUS, LINK _STATUS, VALIDATE_STATUS, INFO_LOG_LENGTH, ATTACHED_SHADERS, ACTIVE_ATTRIBUTES, ACTIVE_ UNIFORMS, ACTIVE_ATTRIBUTES_MAX_LENGTH, ACTIVE_UNIFORM_MAX_LENGTH, TRANSFORM_FEEDBACK_BUFFER_MODE, TRANSFORM_FEEDBACK_ VARYINGS, ACTIVE_UNIFORM_BLOCKS, TRANSFORM_FEEDBACK_VARYING_MAX_LENGTH, ACTIVE_UNIFORM_BLOCK_MAX_NAME_LENGTH, GEOMETRY_VERTICES_OUT, GEOMETRY_{INPUT, OUTPUT}_TYPE, GEOMETRY_SHADER_INVOCATIONS, TESS_CONTROL_OUTPUT_VERTICES, TESS_GEN_MODE, TESS_GEN_SPACING, TESS_GEN_VERTEX_ORDER, TESS_GEN_POINT_MODE, PROGRAM_SEPARABLE, PROGRAM_BINARY_{LENGTH, RETRIEVABLE_HINT}

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

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

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

void **GetProgramPipelineInfoLog**(uint *pipeline*, sizei *bufSize*, sizei **length*, char **infoLog*);

Rasterization [3]

Enable/Disable(*target*)
target: RASTERIZER_DISCARD, MULTISAMPLE, SAMPLE_SHADING

Multisampling [3.3.1]

Use to antialias points, lines, polygons, bitmaps, and images.

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

void **MinSampleShading**(clampf *value*);

Points [3.4]

void **PointSize**(float *size*);

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

void **PointParameter{if}v**(enum *pname*, const T *params*);
pname: POINT_SIZE_MIN, POINT_SIZE_MAX, POINT_DISTANCE_ATTENUATION, POINT_FADE_THRESHOLD_SIZE, POINT_SPRITE_COORD_ORIGIN
param, params: LOWER_LEFT, UPPER_LEFT, pointer to point fade threshold

Enable/Disable (*target*)
target: VERTEX_PROGRAM_POINT_SIZE, POINT_SMOOTH, POINT_SPRITE.

Line Segments [3.5]

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

Enable/Disable(LINE_SMOOTH)

Other Line Seg. Features [3.5.2]

void **LineStipple**(int *factor*, ushort *pattern*);

Enable/Disable(LINE_STIPPLE)

void **GetIntegerv**(LINE_STIPPLE_PATTERN);

Polygons [3.6]

Enable/Disable(*target*)
target: POLYGON_STIPPLE, POLYGON_SMOOTH, CULL_FACE

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

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

Stippling [3.6.2]

void **PolygonStipple**(const ubyte **pattern*);

void **GetPolygonStipple**(void **pattern*);

Polygon Rasterization & Depth Offset [3.6.3 - 3.6.4] [3.6.4 - 3.6.5]

void **PolygonMode**(enum *face*, enum *mode*);
face: FRONT, BACK, FRONT_AND_BACK
mode: POINT, LINE, FILL

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

Enable/Disable(*target*)
target: POLYGON_OFFSET_{POINT, LINE, FILL}

Pixel Storage Modes [3.7.1]

void **PixelStore{if}**(enum *pname*, T *param*);
pname: {UN}PACK_*x* (where *x* may be SWAP_BYTES, LSB_FIRST, ROW_LENGTH, SKIP_{PIXELS, ROWS}, ALIGNMENT, IMAGE_HEIGHT, SKIP_IMAGES)

Pixel Transfer Modes [3.7.3, 6.1.3]

void **PixelTransfer{if}**(enum *param*, T *value*);
param: MAP_{COLOR, STENCIL}, INDEX_{SHIFT, OFFSET}, *x*_ {SCALE, BIAS}, DEPTH_{SCALE, BIAS}, POST_CONVOLUTION_*x*_{SCALE, BIAS}, POST_COLOR_MATRIX_*x*_{SCALE, BIAS}, (where *x* is RED, GREEN, BLUE, or ALPHA) [Table 3.2]

void **PixelMap{ui us f}v**(enum *map*, sizei *size*, const T *values*);
map: PIXEL_MAP_*x*_TO_*x* (where *x* may be {I,S,R,G,B,A}), PIXEL_MAP_I_TO_{R,G,B,A} [Table 3.3]

void **GetPixelMap{ui us f}v**(enum *map*, T *data*);
map: *see PixelMap{ui us f}v*

Color Table Specification [3.7.3]

void **ColorTable**(enum *target*, enum *internalformat*, sizei *width*, enum *format*, enum *type*, const void **data*);
target: {PROXY_}COLOR_TABLE, {PROXY_}POST_CONVOLUTION_COLOR_TABLE, {PROXY_}POST_COLOR_MATRIX_COLOR_TABLE
internalformat: The formats in [Table 3.16] or [Tables 3.17-3.19] except RED, RG, DEPTH_{COMPONENT, STENCIL} base and sized internal formats in those tables, all sized internal formats with non-fixed internal data types as discussed in [3.9], and RGB9_E5.
format: RED, GREEN, BLUE, ALPHA, RG, RGB, RGBA, BGRA, LUMINANCE, LUMINANCE_ALPHA
type: *see DrawPixels*

Enable/Disable(POST_COLOR_MATRIX_COLOR_TABLE)

void **ColorTableParameter{if}v**(enum *target*, enum *pname*, const T *params*);
target: POST_COLOR_MATRIX_COLOR_TABLE, {POST_CONVOLUTION_}COLOR_TABLE
pname: COLOR_TABLE_SCALE, COLOR_TABLE_BIAS

Alt. Color Table Specification Commands

void **CopyColorTable**(enum *target*, enum *internalformat*, int *x*, int *y*, sizei *width*);

void **ColorSubTable**(enum *target*, sizei *start*, sizei *count*, enum *format*, enum *type*, void **data*);

void **CopyColorSubTable**(enum *target*, sizei *start*, int *x*, int *y*, sizei *count*);
target and *pname:* *see ColorTableParameter{if}v*

Color Table Query [6.1.8]

void **GetColorTable**(enum *target*, enum *format*, enum *type*, void **table*);
target: *see ColorTableParameter{if}v*

(more parameters ↴)

format: RED, GREEN, BLUE, ALPHA, RGB, RGBA, BGR, BGRA, LUMINANCE{_ALPHA}
type: UNSIGNED_{BYTE, SHORT, INT}, BYTE, SHORT, INT, UNSIGNED_BYTE_3_3_2, UNSIGNED_BYTE_2_3_3_REV, UNSIGNED_SHORT_5_6_5{_REV}, UNSIGNED_SHORT_4_4_4_4{_REV}, UNSIGNED_SHORT_5_5_5_1, UNSIGNED_SHORT_1_5_5_5_REV, UNSIGNED_INT_8_8_8_8{_REV}, UNSIGNED_INT_10_10_10_2, UNSIGNED_INT_2_10_10_10_REV

void **GetColorTableParameter{if}v**(enum *target*, enum *pname*, T *params*);
target: *see ColorTable*
pname: COLOR_TABLE_*x* (where *x* may be SCALE, BIAS, FORMAT, COLOR_TABLE_WIDTH, RED_SIZE, GREEN_SIZE, BLUE_SIZE, ALPHA_SIZE, LUMINANCE_SIZE, INTENSITY_SIZE)

Convolution Filter Specification [3.7.3]

Enable/Disable(POST_CONVOLUTION_COLOR_TABLE)

void **ConvolutionFilter2D**(enum *target*, enum *internalformat*, sizei *width*, sizei *height*, enum *format*, enum *type*, const void **data*);
target: CONVOLUTION_2D
internalformat: *see ColorTable*
format: RED, GREEN, BLUE, ALPHA, RG, RGB, RGBA, BGRA, LUMINANCE, LUMINANCE_ALPHA
type: BYTE, SHORT, INT, FLOAT, HALF_FLOAT, UNSIGNED_{BYTE, SHORT, INT}

void **ConvolutionFilter1D**(enum *target*, enum *internalformat*, sizei *width*, enum *format*, enum *type*, const void **data*);
target: CONVOLUTION_1D
internalformat, format, type: *see ConvolutionFilter2D*

void **ConvolutionParameter{if}v**(enum *target*, enum *pname*, const T *params*);
target: CONVOLUTION_2D
pname: CONVOLUTION_FILTER_{SCALE, BIAS}

void **SeparableFilter2D**(enum *target*, enum *internalformat*, sizei *width*, sizei *height*, enum *format*, enum *type*, const void **row*, const void **column*);
target: SEPARABLE_2D
internalformat, format, type: *see ConvolutionFilter2D*

Alt. Convolution Filter Spec. Commands

void **CopyConvolutionFilter2D**(enum *target*, enum *internalformat*, int *x*, int *y*, sizei *width*, sizei *height*);
target: CONVOLUTION_2D
internalformat: *see ConvolutionFilter2D*

void **CopyConvolutionFilter1D**(enum *target*, enum *internalformat*, int *x*, int *y*, sizei *width*);
target: CONVOLUTION_1D
internalformat: *see ConvolutionFilter2D*

Convolution Query [6.1.9]

void **GetConvolutionFilter**(enum *target*, enum *format*, enum *type*, void **image*);
target: CONVOLUTION_1D, CONVOLUTION_2D
format and *type:* *see GetColorTable*

void **GetSeparableFilter**(enum *target*, enum *format*, enum *type*, void **row*, void **column*, void **span*);
target: SEPARABLE_2D
format and *type:* *see GetColorTable*

void **GetConvolutionParameter{if}v**(enum *target*, enum *pname*, T *params*);
target: CONVOLUTION_{1D, 2D}, SEPARABLE_2D
pname: {MAX_}CONVOLUTION_{WIDTH, HEIGHT}, CONVOLUTION_*x* (where *x* may be FILTER_BIAS, BORDER_COLOR, BORDER_MODE, FILTER_SCALE, FORMAT)

Histogram Table Specification [3.7.3]

void **Histogram**(enum *target*, sizei *width*, enum *internalformat*, boolean *sink*);
target: HISTOGRAM, PROXY_HISTOGRAM
internalformat: *see ColorTable* except 1, 2, 3, and 4

Histogram Query [6.1.10]

void **GetHistogram**(enum *target*, boolean *reset*, enum *format*, enum *type*, void **values*);
target: HISTOGRAM
format and *type:* *see GetColorTable*

void **ResetHistogram**(enum *target*);
target: HISTOGRAM

void **GetHistogramParameter{if}v**(enum *target*, enum *pname*, T *params*);
target: HISTOGRAM, PROXY_HISTOGRAM
pname: HISTOGRAM_*x* (where *x* may be FORMAT, WIDTH, {RED, GREEN, BLUE, ALPHA}_SIZE, LUMINANCE_SIZE, SINK)

Minmax Table Specification [3.7.3]

Enable/Disable(MINMAX)

void **Minmax**(enum *target*, enum *internalformat*, boolean *sink*);
target: MINMAX
internalformat: *see ColorTable*, omitting the values 1, 2, 3, 4 and INTENSITY base and sized internal formats

Minmax Query [6.1.11]

void **GetMinmax**(enum *target*, boolean *reset*, enum *format*, enum *type*, void **values*);
target: MINMAX
format and *type:* *see GetColorTable*

void **ResetMinmax**(enum *target*);
target: MINMAX

void **GetMinmaxParameter{if}v**(enum *target*, enum *pname*, T *params*);
target: MINMAX
pname: MINMAX_FORMAT, MINMAX_SINK

(Rasterization Continue >)

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Rasterization (continued)

Rasterization of Pixel Rectangles [4.3.1] [3.7.5]

void **DrawPixels**(sizei *width*, sizei *height*, enum *format*, enum *type*, const void **data*);

format: {COLOR|STENCIL}_INDEX, RED, GREEN, BLUE, DEPTH_{COMPONENT, STENCIL}, ALPHA, RG, RGB, RGBA, BGR, BGRA, LUMINANCE{_ALPHA} (*_INTEGER formats from {Table 3.6} not supported)

type: BITMAP, BYTE, SHORT, INT, FLOAT, HALF_FLOAT, UNSIGNED_{BYTE, SHORT, INT}, or value from [Table 3.5]

void **ClampColor**(enum *target*, enum *clamp*);

target: CLAMP_{READ,FRAGMENT, VERTEX}_COLOR
clamp: TRUE, FALSE, FIXED_ONLY

void **PixelZoom**(float *zx*, float *zy*);

Pixel Transfer Operations [3.7.6]

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

target: CONVOLUTION_{1D, 2D}, SEPARABLE_2D
pname: CONVOLUTION_BORDER_MODE
param: REDUCE, {CONSTANT, REPLICATE_}BORDER

Bitmaps [3.8]

void **Bitmap**(sizei *w*, sizei *h*, float *xb0*, float *yb0*, float *xbi*, float *ybi*, const ubyte **data*);

Whole Framebuffer

Selecting a Buffer for Writing [4.2.1]

void **DrawBuffer**(enum *buf*);

buf: NONE, FRONT{_LEFT, _RIGHT}, LEFT, RIGHT, BACK{_LEFT, _RIGHT}, FRONT_AND_BACK, COLOR_ATTACHMENT*i* (*i* = [0, MAX_COLOR_ATTACHMENTS - 1]), AUX*i* (*i* =[0, AUX_BUFFERS - 1])

void **DrawBuffers**(sizei *n*, const enum **bufs*);

bufs: NONE, FRONT_{LEFT, RIGHT}, BACK_LEFT, BACK_RIGHT, COLOR_ATTACHMENT*i* (*i* = [0, MAX_COLOR_ATTACHMENTS - 1]), AUX*i* (*i* = [0, AUX_BUFFERS - 1])

Fine Control of Buffer Updates [4.2.2]

void **IndexMask**(uint *mask*);

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 [4.2.3]

void **Clear**(bitfield *buf*);

buf: Bitwise OR of ACCUM_BUFFER_BIT, {COLOR, DEPTH, STENCIL}_BUFFER_BIT,

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

void **ClearIndex**(float *index*);

void **ClearDepth**(clampd *d*);

void **ClearDepthf**(clampf *d*);

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

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

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**

Accumulation Buffer [4.2.4]

void **Accum**(enum *op*, float *value*);

op: **ACCUM, LOAD, RETURN, MULT, ADD.**

Color Sum, Fog, and Hints

Color Sum [3.10]

Enable/Disable(COLOR_SUM)

Fog [3.11]

Enable/Disable(FOG)

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

void **Fog{if}v**(enum *pname*, T *params*);

pname: FOG_MODE, FOG_COORD_SRC, FOG_DENSITY, FOG_START, FOG_END, FOG_COLOR, FOG_INDEX

Hints [5.4] [5.8]

void **Hint**(enum *target*, enum *hint*);

target: FRAGMENT_SHADER_DERIVATIVE_HINT, TEXTURE_COMPRESSION_HINT, PERSPECTIVE_CORRECTION_HINT, {LINE, POLYGON,POINT}_SMOOTH_HINT, FOG_HINT, GENERATE_MIPMAP_HINT
hint: FASTEST, NICEST, DONT_CARE

Texturing [3.8] [3.9]

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

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

Texture Objects [3.8.1] [3.9.1]

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

target: TEXTURE_{1, 2}D{_ARRAY}, TEXTURE_{3D, RECTANGLE, BUFFER}, TEXTURE_CUBE_MAP{_ARRAY}, TEXTURE_2D_MULTISAMPLE{_ARRAY}

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

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

boolean **AreTexturesResident**(sizei *n*, uint **textures*, boolean **residences*);

void **PrioritizeTextures**(sizei *n*, uint **textures*, const clampf **priorities*);

Sampler Objects [3.8.2] [3.9.2]

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

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

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

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

pname: TEXTURE_WRAP_{S, T, R}, TEXTURE_{MIN, MAG}_{FILTER, LOD}, TEXTURE_BORDER_COLOR, TEXTURE_LOD_BIAS, TEXTURE_COMPARE_{MODE, FUNC}

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

Texture Image Spec. [3.8.3] [3.9.3]

void **TexImage3D**(enum *target*, int *level*, int *internalformat*, sizei *width*, sizei *height*, sizei *depth*, int *border*, enum *format*, enum *type*, const void **data*);

target: {PROXY_}TEXTURE_{3D, 2D_ARRAY}, {PROXY_}TEXTURE_CUBE_MAP_ARRAY
internalformat: ALPHA, DEPTH_COMPONENT, DEPTH_STENCIL, LUMINANCE{_ALPHA}, RED, INTENSITY, RG, RGB, RGBA; or a sized internal format from [Tables 3.12-3.13] [Tables 3.17-3.19]; COMPRESSED_{SIGNED_}{RED_RGTC1,RG_RGTC2}, or a generic comp. format in [Table 3.14] [Table 3.20]
format: COLOR_INDEX, DEPTH_{COMPONENT, STENCIL}, RED, GREEN, BLUE, ALPHA, RG, RGB, RGBA, BGR, BGRA, LUMINANCE{_ALPHA}, {RED, GREEN, BLUE, ALPHA}_INTEGER, {RG, RGB, RGBA, BGR}_INTEGER, BGRA_INTEGER [Table 3.3] [Table 3.6]
type: BITMAP, {UNSIGNED_}BYTE, {UNSIGNED_}SHORT, {UNSIGNED_}INT, {HALF_}FLOAT, or a value from [Table 3.2] [Table 3.5]

void **TexImage2D**(enum *target*, int *level*, int *internalformat*, sizei *width*, sizei *height*, int *border*, enum *format*, enum *type*, const void **data*);

target: {PROXY_}TEXTURE_{2D, RECTANGLE,CUBE_MAP}, {PROXY_}TEXTURE_1D_ARRAY, TEXTURE_CUBE_MAP_{POSITIVE, NEGATIVE}_{X, Y, Z},
internalformat, format, and *type:* ***see TexImage3D***

void **TexImage1D**(enum *target*, int *level*, int *internalformat*, sizei *width*, int *border*, enum *format*, enum *type*, const void **data*);

target: TEXTURE_1D, PROXY_TEXTURE_1D
type, internalformat, and *format:* ***see TexImage3D***

Alternate Texture Image Spec. [3.8.4] [3.9.4]

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

target: TEXTURE_{2D, RECTANGLE, 1D_ARRAY}, TEXTURE_CUBE_MAP_{POSITIVE, NEGATIVE}_{X, Y, Z}
internalformat: ***see TexImage2D***, except 1, 2, 3, 4

void **CopyTexImage1D**(enum *target*, int *level*, enum *internalformat*, int *x*, int *y*, sizei *width*, int *border*);

target: TEXTURE_1D
internalformat: ***see TexImage1D***, except 1, 2, 3, 4

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*);

(see parameters ↴)

target: TEXTURE_3D, TEXTURE_2D_ARRAY, TEXTURE_CUBE_MAP_ARRAY
format and *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 CopyTexImage2D***
format and *type:* ***see TexImage2D***

void **TexSubImage1D**(enum *target*, int *level*, int *xoffset*, sizei *width*, enum *format*, enum *type*, const void **data*);

target: TEXTURE_1D
format, type: ***see TexImage1D***

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

target: ***see TexSubImage3D***

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

target: TEXTURE_2D, TEXTURE_1D_ARRAY, TEXTURE_RECTANGLE, TEXTURE_CUBE_MAP_{POSITIVE, NEGATIVE}_{X, Y, Z}

void **CopyTexSubImage1D**(enum *target*, int *level*, int *xoffset*, int *x*, int *y*, sizei *width*);

target: TEXTURE_1D

Compressed Texture Images [3.8.5] [3.9.5]

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: COMPRESSED_RED_RGTC1_RED, COMPRESSED_SIGNED_RED_RGTC1_RED, COMPRESSED_RG_RGTC2_RG, COMPRESSED_SIGNED_RG_RGTC2

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

target: ***see TexImage2D***, omitting compressed rectangular texture formats
internalformat: ***see CompressedTexImage3D***

void **CompressedTexImage1D**(enum *target*, int *level*, enum *internalformat*, sizei *width*, int *border*, sizei *imageSize*, const void **data*);

target: TEXTURE_1D, PROXY_TEXTURE_1D
internalformat: values are implementation-dependent

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 TexSubImage3D***
format: ***see internalformat for CompressedTexImage3D***

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

target: ***see TexSubImage2D***
format: ***see TexImage2D***

void **CompressedTexSubImage1D**(enum *target*, int *level*, int *xoffset*, sizei *width*, enum *format*, sizei *imageSize*, const void **data*);

target: ***see TexSubImage1D***
format: ***see TexImage1D***

Multisample Textures [3.8.6] [3.9.6]

void **TexImage3DMultisample**(enum *target*, sizei *samples*, int *internalformat*, sizei *width*, sizei *height*, sizei *depth*, boolean *fixedsamplelocations*);

target: {PROXY_}TEXTURE_2D_MULTISAMPLE_ARRAY
internalformat: ALPHA, RED, RG, RGB, RGBA, DEPTH_{COMPONENT, STENCIL}, STENCIL_INDEX, or sized internal formats corresponding to these base formats

void **TexImage2DMultisample**(enum *target*, sizei *samples*, int *internalformat*, sizei *width*, sizei *height*, boolean *fixedsamplelocations*);

target: {PROXY_}TEXTURE_2D_MULTISAMPLE
internalformat: ***see TexImage3DMultisample***

Buffer Textures [3.8.7] [3.9.7]

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

(see parameters ↴)

target: TEXTURE_BUFFER
internalformat: R8{I,UI}, R16{F, I, UI}, R32{F, I, UI}, RG8{I, UI}, RG16{F, I, UI}, RG32{F, I, UI}, RGB32{F, I, UI}, RGBA8{I, UI}, RGBA16{F, I, UI}, RGBA32{F, I, UI}

Texture Parameters [3.8.8] [3.9.8]

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

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

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

target: TEXTURE_{1D,2D,3D}, TEXTURE_{1D,2D}_ARRAY, TEXTURE_RECTANGLE, TEXTURE_CUBE_MAP{_ARRAY}
pname: TEXTURE_WRAP_{S, T, R}, TEXTURE_PRIORITY, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_LOD_BIAS, TEXTURE_BORDER_COLOR, DEPTH_TEXTURE_MODE, TEXTURE_{MIN, MAX}_LOD, GENERATE_MIPMAP, TEXTURE_SWIZZLE_{R, G, B, A, RGBA}, TEXTURE_{BASE, MAX}_LEVELS, TEXTURE_COMPARE_{MODE, FUNC} [Table 3.16] [Table 3.22]

Cube Map Texture Select [3.8.10] [3.9.10]

Enable/Disable(TEXTURE_CUBE_MAP_SEAMLESS)

Texture Minification [3.8.11] [3.9.11]

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

target: TEXTURE_{1D, 2D, 3D}, TEXTURE_{1D, 2D}_ARRAY, TEXTURE_CUBE_MAP{_ARRAY}

Texture Environments & Functions [3.9.16]

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

void **TexEnv{if}v**(enum *target*, enum *pname*, const T *params*);

target: TEXTURE_{FILTER_CONTROL, ENV}, POINT_SPRITE
pname: TEXTURE_LOD_BIAS, TEXTURE_ENV_MODE, TEXTURE_ENV_COLOR, COMBINE_{RGB, ALPHA}, {RGB, ALPHA}_SCALE, COORD_REPLACE, SRC*n*_RGB, SRC*n*_ALPHA, OPERAND*n*_RGB, OPERAND*n*_ALPHA (where *n* is [0, 1, 2])

Texture Application [3.9.20]

Enable/Disable(*param*)

param: TEXTURE_{1D, 2D, 3D}, TEXTURE_CUBE_MAP

Enumerated Queries [6.1.3]

void **GetTexEnv{if}v**(enum *env*, enum *value*, T *data*);

env: POINT_SPRITE, TEXTURE_{ENV,FILTER_CONTROL}

void **GetTexGen{ifd}v**(enum *coord*, enum *value*, T *data*);

coord: S, T, R, Q

void **GetTexParameter{if}v**(enum *target*, enum *value*, T *data*);

void **GetTexParameterI{i ui}v**(enum *target*, enum *value*, T *data*);

target: TEXTURE_{1D, 2D, 3D,RECTANGLE}, TEXTURE_{1D, 2D}_ARRAY, TEXTURE_CUBE_MAP{_ARRAY}
value: TEXTURE_{RESIDENT, PRIORITY}, DEPTH_TEXTURE_MODE, GENERATE_MIPMAP, TEXTURE_{BASE, MAX}_LEVEL, TEXTURE_BORDER_COLOR, TEXTURE_LOD_BIAS, TEXTURE_COMPARE_{MODE, FUNC}, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_MAX_{LEVEL, LOD}, TEXTURE_MIN_LOD, TEXTURE_SWIZZLE_{R, G, B, A, RGBA}, TEXTURE_WRAP_{S, T, R} [Table 3.16] [Table 3.22]

void **GetTexLevelParameter{if}v**(enum *target*, int *lod*, enum *value*, T *data*);

target: {PROXY_}TEXTURE_{1D, 2D, 3D}, TEXTURE_BUFFER, PROXY_TEXTURE_CUBE_MAP, {PROXY_}TEXTURE_{1D, 2D}_ARRAY, {PROXY_}TEXTURE_CUBE_MAP_ARRAY, {PROXY_}TEXTURE_RECTANGLE, TEXTURE_CUBE_MAP_{POSITIVE, NEGATIVE}_{X, Y, Z}, TEXTURE_2D_MULTISAMPLE{_ARRAY}, PROXY_TEXTURE_2D_MULTISAMPLE, PROXY_TEXTURE_2D_MULTISAMPLE{_ARRAY}
value: TEXTURE_{WIDTH, HEIGHT, DEPTH}, TEXTURE_{BORDER, COMPONENTS, SAMPLES}, TEXTURE_FIXED_SAMPLE_LOCATIONS, TEXTURE_{INTERNAL_FORMAT, SHARED_SIZE}, TEXTURE_COMPRESSED{_IMAGE_SIZE}, TEXTURE_BUFFER_DATA_STORE_BINDING, TEXTURE_x_{SIZE, TYPE} (where x can be RED, GREEN, BLUE, ALPHA, LUMINANCE, INTENSITY, DEPTH, STENCIL)

(Texturing Continue >)

Texturing (continued)

Texture Queries [6.1.4]

void **GetTexImage**(enum *tex*, int *lod*, enum *format*, enum *type*, void **img*);
tex: TEXTURE_{1, 2}D{_ARRAY}, TEXTURE_3D, TEXTURE_RECTANGLE, TEXTURE_CUBE_MAP_ARRAY, TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}
format: *see TexImage3D*
type: BITMAP, {UNSIGNED_}BYTE, UNSIGNED_{SHORT}, {UNSIGNED_}INT, {HALF_}FLOAT, or value from [Table 3.2] [Table 3.5]

void **GetCompressedTexImage**(enum *target*, int *lod*, void **img*);
target: *see "tex" for GetTexImage*

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

Sampler Queries [6.1.5]

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

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

void **GetSamplerParameterI{i ui}v**(uint *sampler*, enum *pname*, T **params*);
pname: TEXTURE_WRAP_{S, T, R}, TEXTURE_{MIN, MAG}_FILTER, TEXTURE_BORDER_COLOR, TEXTURE_LOD_BIAS, TEXTURE_{MIN, MAX}_LOD, TEXTURE_COMPARE_{MODE, FUNC}

Per-Fragment Operations

Scissor Test [4.1.2]

Enable/Disable(SCISSOR_TEST)

Enablei/Disablei(SCISSOR_TEST, uint *index*)

void **ScissorArrayv**(uint *first*, sizei *count*, const int **v*);

void **ScissorIndexed**(uint *index*, int *left*, int *bottom*, sizei *width*, sizei *height*);

void **ScissorIndexedv**(uint *index*, int **v*);

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

Multisample Fragment Operations [4.1.3]

Enable/Disable(*target*)
target: SAMPLE_ALPHA_TO_{COVERAGE, ONE}, SAMPLE_{COVERAGE, MASK}, MULTISAMPLE

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

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

Alpha Test [4.1.4]

Enable/Disable(ALPHA_TEST)

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

Stencil Test [4.1.4] [4.1.5]

Enable/Disable(STENCIL_TEST)

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

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

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

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

Depth Buffer Test [4.1.5] [4.1.6]

Enable/Disable(DEPTH_TEST)

void **DepthFunc**(enum *func*);
func: *see StencilOpSeparate*

Occlusion Queries [4.1.6] [4.1.7]

BeginQuery(enum *target*, uint *id*);

EndQuery(enum *target*);
target: SAMPLES_PASSED, ANY_SAMPLES_PASSED

Blending [4.1.7] [4.1.8]

Enable/Disable(BLEND)

Enablei/Disablei(BLEND, uint *index*)

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

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

void **BlendEquationSeparate**(enum *modeRGB*, enum *modeAlpha*);
mode, modeRGB, and *modeAlpha*: FUNC_ADD, FUNC_{SUBTRACT, REVERSE}_SUBTRACT, MIN, MAX

void **BlendEquationSeparatei**(uint *buf*, enum *modeRGB*, enum *modeAlpha*);
mode, modeRGB, and *modeAlpha*: *see BlendEquationSeparate*

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

void **BlendFunci**(uint *buf*, enum *src*, enum *dst*);
srd, dst: see BlendFuncSeparate

void **BlendFuncSeparate**(enum *srcRGB*, enum *dstRGB*, enum *srcAlpha*, enum *dstAlpha*);
src, dst, srcRGB, dstRGB, srcAlpha, dstAlpha: ZERO, ONE, SRC_{COLOR, ALPHA}, DST_{COLOR, ALPHA}, SRC_ALPHA_SATURATE, CONSTANT_{COLOR, ALPHA}, ONE_MINUS_SRC_{COLOR, ALPHA}, ONE_MINUS_DST_{COLOR, ALPHA}, ONE_MINUS_CONSTANT_{COLOR, ALPHA}, {ONE_MINUS_}SRC1_ALPHA

void **BlendFuncSeparatei**(uint *buf*, enum *srcRGB*, enum *dstRGB*, enum *srcAlpha*, enum *dstAlpha*);
dst, dstRGB, dstAlpha, src, srcRGB, srcAlpha: see BlendFuncSeparate

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

Dithering [4.1.9] [4.1.10]

Enable/Disable(DITHER)

Logical Operation [4.1.10] [4.1.11]

Enable/Disable(enum *op*)
op: INDEX_LOGIC_OP, LOGIC_OP, COLOR_LOGIC_OP

void **LogicOp**(enum *op*);
op: CLEAR, AND, AND_REVERSE, COPY, AND_INVERTED, NOOP, OR, OR, NOR, EQUIV, INVERT, OR_REVERSE, COPY_INVERTED, OR_INVERTED, NAND, SET

Framebuffer Objects

Binding and Managing [4.4.1]

void **BindFramebuffer**(enum *target*, uint *framebuffer*);
target: {DRAW, READ_}FRAMEBUFFER

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

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

Attaching Images [4.4.2]

Renderbuffer Objects

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

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

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

void **RenderbufferStorageMultisample**(enum *target*, sizei *samples*, enum *internalformat*, sizei *width*, sizei *height*);
(parameters ↴)
target: RENDERBUFFER
internalformat: see TexImage2DMultisample

void **RenderbufferStorage**(enum *target*, enum *internalformat*, sizei *width*, sizei *height*);
target and *internalformat: see RenderbufferStorageMultisample*

Attaching Renderbuffer Images

void **FramebufferRenderbuffer**(enum *target*, enum *attachment*, enum *renderbuffertarget*, uint *renderbuffer*);
target: {DRAW, READ_}FRAMEBUFFER
attachment: {DEPTH, STENCIL}_ATTACHMENT, DEPTH_STENCIL_ATTACHMENT, COLOR_ATTACHMENT*i* (where *i* is [0, MAX_COLOR_ATTACHMENTS - 1])
renderbuffertarget: RENDERBUFFER

Attaching Texture Images

void **FramebufferTexture**(enum *target*, enum *attachment*, uint *texture*, int *level*);
target: {DRAW, READ_}FRAMEBUFFER
attachment: see FramebufferRenderbuffer

void **FramebufferTexture3D**(enum *target*, enum *attachment*, enum *textarget*, uint *texture*, int *level*, int *layer*);
textarget: TEXTURE_3D
target and *attachment: see framebufferRenderbuffer*

void **FramebufferTexture2D**(enum *target*, enum *attachment*, enum *textarget*, uint *texture*, int *level*);
textarget: TEXTURE_{RECTANGLE, 3D}, TEXTURE_2D_MULTISAMPLE{_ARRAY}, TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_NEGATIVE_{X, Y, Z}
target, attachment: see FramebufferRenderbuffer

void **FramebufferTexture1D**(enum *target*, enum *attachment*, enum *textarget*, uint *texture*, int *level*);
textarget: TEXTURE_1D
target, attachment: see FramebufferRenderbuffer

void **FramebufferTextureLayer**(enum *target*, enum *attachment*, uint *texture*, int *level*, int *layer*);
target, attachment: see FramebufferTexture3D

Framebuffer Completeness [4.4.4]

enum **CheckFramebufferStatus**(enum *target*);
target: {DRAW, READ}FRAMEBUFFER, FRAMEBUFFER
returns: FRAMEBUFFER_COMPLETE or a constant indicating the violating value

Framebuffer Object Queries [6.1.13] [6.1.19]

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

void **GetFramebufferAttachmentParameteriv**(enum *target*, enum *attachment*, enum *pname*, int **params*);
target: {DRAW, READ}_FRAMEBUFFER, FRAMEBUFFER
attachment: FRONT_{LEFT, RIGHT}, BACK_{LEFT,RIGHT}, COLOR_ATTACHMENT*i*, AUX*i*, DEPTH, STENCIL, {DEPTH, STENCIL}_ATTACHMENT, DEPTH_STENCIL_ATTACHMENT
pname: FRAMEBUFFER_ATTACHMENT_*x* (where *x* may be OBJECT_TYPE, OBJECT_NAME, RED_SIZE, GREEN_SIZE, BLUE_SIZE, ALPHA_SIZE, DEPTH_SIZE, STENCIL_SIZE, COMPONENT_TYPE, COLOR_ENCODING, TEXTURE_LEVEL, LAYERED, TEXTURE_CUBE_MAP_FACE, TEXTURE_LAYER)

Renderbuffer Object Queries [6.1.14] [6.1.20]

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

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

Special Functions

Evaluators [5.1]

Evaluators provide a means to use a polynomial or rational polynomial mapping to produce vertex, normal, and texture coordinates, and colors. Transformations, lighting, primitive assembly, rasterization, and per-pixel operations are not affected.

void **Map1{fd}**(enum *target*, T *u1*, T *u2*, int *stride*, int *order*, T *points*);
target: MAP1_VERTEX_{3,4}, MAP1_{INDEX, NORMAL}, MAP1_COLOR_4, MAP1_TEXTURE_COORD_{1,2,3,4}

void **Map2{fd}**(enum *target*, T *u1*, T *u2*, int *ustride*, int *uorder*, T *v1*, T *v2*, int *vstride*, int *vorder*, const T *points*);
target: see Map1, except replace MAP1 with MAP2

void **EvalCoord{12}{fd}**(T *arg*);

void **EvalCoord{12}{fd}v**(const T *arg*);

void **MapGrid1{fd}**(int *n*, T *u1*, T *u2*);

void **MapGrid2{fd}**(int *nu*, T *u1*, T *u2*, int *nv*, T *v1*, T *v2*);

void **EvalMesh1**(enum *mode*, int *p1*, int *p2*);
mode: POINT, LINE

void **EvalMesh2**(enum *mode*, int *p1*, int *p2*, int *q1*, int *q2*);
mode: FILL, POINT, LINE

void **EvalPoint1**(int *p*);

void **EvalPoint2**(int *p*, int *q*);

Enumerated Query [6.1.3]

void **GetMap{ifd}v**(enum *map*, enum *value*, T *data*);
map: see target for Map1
value: ORDER, COEFF, DOMAIN

Selection [5.2]

Determine which primitives are drawn into a region of a window. The region is defined by the current model-view and perspective matrices.

void **InitNames**(void);

void **PopName**(void);

void **PushName**(uint *name*);

void **LoadName**(uint *name*);

int **RenderMode**(enum *mode*);
mode: RENDER, SELECT, FEEDBACK

void **SelectBuffer**(sizei *n*, uint **buffer*);

Feedback [5.3]

When in feedback mode, framebuffer updates are not performed. Instead, information about primitives that would have otherwise been rasterized is returned to the application via the feedback buffer.

void **FeedbackBuffer**(sizei *n*, enum *type*, float **buffer*);
type: 2D, 3D, 3D_COLOR, 3D_COLOR_TEXTURE, 4D_COLOR_TEXTURE

void **PassThrough**(float *token*);

Timer Queries [5.1] [5.4]

Timer queries use query objects to track the amount of time needed to fully complete a set of GL commands, or to determine the current time of the GL.

void **QueryCounter**(uint *id*, TIMESTAMP);

void **GetInteger64v**(TIMESTAMP, int64 **data*);

Display Lists [5.5]

A display list is a group of GL commands and arguments that has been stored for subsequent execution. The GL may be instructed to process a particular display list (possibly repeatedly) by providing a number that uniquely specifies it.

void **NewList**(uint *n*, enum *mode*);
mode: COMPILE, COMPILE_AND_EXECUTE

void **EndList**(void);

void **CallList**(uint *n*);

void **CallLists**(sizei *n*, enum *type*, const void **lists*);
type: BYTE, UNSIGNED_BYTE, SHORT, {2,3,4}_BYTES, UNSIGNED_SHORT, INT, UNSIGNED_INT, FLOAT

void **ListBase**(uint *base*);

uint **GenLists**(sizei *s*);

boolean **IsList**(uint *list*);

void **DeleteLists**(uint *list*, sizei *range*);

Synchronization

Flush and Finish [5.2] [5.6]

void **Flush**(void);

void **Finish**(void);

Sync Objects and Fences [5.3] [5.7]

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

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

Waiting for Sync Objects [5.3.1] [5.7.1]

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

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

Sync Object Queries [6.1.8] [6.1.14]

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

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

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 **GetDoublev**(enum *pname*, double **data*);
void **GetBooleani_v**(enum *target*, uint *index*, boolean **data*);
void **GetIntegeri_v**(enum *target*, uint *index*, int **data*);
void **GetFloati_v**(enum *target*, uint *index*, float **data*);
void **GetInteger64i_v**(enum *target*, uint *index*, int64 **data*);
boolean **IsEnabled**(enum *cap*);
boolean **IsEnabledi**(enum *target*, uint *index*);

Pointer & String Queries [6.1.6] [6.1.12]

void **GetPointerv**(enum *pname*, void ***params*);
pname: {SELECTION, FEEDBACK}_BUFFER_POINTER, {VERTEX, NORMAL, COLOR}_ARRAY_POINTER, {SECONDARY_COLOR, INDEX}_ARRAY_POINTER, {TEXTURE, FOG}_COORD_ARRAY_POINTER, EDGE_FLAG_ARRAY_POINTER

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

ubyte ***GetStringi**(enum *name*, uint *index*);
name: EXTENSIONS
index: range is [0, NUM_EXTENSIONS - 1]

Saving and Restoring State [6.1.21]

void **PushAttrib**(bitfield *mask*);
mask: ALL_ATTRIB_BITS, or the bitwise OR of the attribute groups in [Table 6.3].
void **PushClientAttrib**(bitfield *mask*);
mask: CLIENT_ALL_ATTRIB_BITS, or the bitwise OR of the attribute groups in [Table 6.3].
void **PopAttrib**(void);
void **PopClientAttrib**(void);

Reading, and Copying Pixels

Reading Pixels [4.3.1] [4.3.2]

void **ReadPixels**(int *x*, int *y*, sizei *width*, sizei *height*, enum *format*, enum *type*, void **data*);
format: {COLOR, STENCIL}_INDEX, DEPTH_{COMPONENT, STENCIL}, RED, GREEN, BLUE, RG, RGB, RGBA, LUMINANCE{_ALPHA}, BGR, {RED, GREEN, BLUE, ALPHA, RG, RGB, RGBA, BGR, BGRA}_INTEGER, BGRA, ALPHA [Table 3.3] [Table 3.6]
type: {HALF_}FLOAT, {UNSIGNED_}BYTE, {UNSIGNED_}SHORT, BITMAP, {UNSIGNED_}INT, FLOAT_32_UNSIGNED_INT_24_8_REV, and UNSIGNED_{BYTE, SHORT, INT}_* values from [Table 3.2] [Table 3.5]
(more parameters ↴)

void **ReadBuffer**(enum *src*);
src: NONE, FRONT{_LEFT, RIGHT}, LEFT, RIGHT, BACK{_LEFT, RIGHT}, FRONT_AND_BACK, AUX*i* (*i* = [0, AUX_BUFFERS - 1]), COLOR_ATTACHMENT*i* (*i* = [0, MAX_COLOR_ATTACHMENTS - 1])

Copying Pixels [4.3.2] [4.3.3]

void **CopyPixels**(int *x*, int *y*, sizei *width*, sizei *height*, enum *type*);
type: COLOR, STENCIL, DEPTH, DEPTH_STENCIL

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, NEAREST

Also see DrawPixels, ClampColor, and PixelZoom in the Rasterization section of this reference card.

The OpenGL® Shading Language is used to create shaders for each of the programmable processors contained in the OpenGL processing pipeline.

[n.n.n] and **[Table n.n]** refer to sections and tables in the OpenGL Shading Language 4.10 specification at www.opengl.org/registry

Content shown in blue is removed from the OpenGL 4.1 core profile and present only in the OpenGL 4.1 compatibility profile.

Types [4.1]

Transparent Types

void	no function return value
bool	Boolean
int, uint	signed/unsigned integers
float	single-precision floating-point scalar
double	double-precision floating scalar
vec2, vec3, vec4	floating point vector
dvec2, dvec3, dvec4	double precision floating-point vectors
bvec2, bvec3, bvec4	Boolean vectors
ivec2, ivec3, ivec4 uvec2, uvec3, uvec4	signed and unsigned integer vectors
mat2, mat3, mat4	2x2, 3x3, 4x4 float matrix
mat2x2, mat2x3, mat2x4	2-column float matrix of 2, 3, or 4 rows
mat3x2, mat3x3, mat3x4	3-column float matrix of 2, 3, or 4 rows
mat4x2, mat4x3, mat4x4	4-column float matrix of 2, 3, or 4 rows
dmat2, dmat3, dmat4	2x2, 3x3, 4x4 double-precision float matrix
dmat2x2, dmat2x3, dmat2x4	2-col. double-precision float matrix of 2, 3, 4 rows
dmat3x2, dmat3x3, dmat3x4	3-col. double-precision float matrix of 2, 3, 4 rows
dmat4x2, dmat4x3, dmat4x4	4-column double-precision float matrix of 2, 3, 4 rows

Floating-Point Sampler Types (Opaque)

sampler[1,2,3]D	1D, 2D, or 3D texture
samplerCube	cube mapped texture
sampler2DRect	rectangular texture
sampler[1,2]DShadow	1D,2D depth texture/ compare
sampler2DRectShadow	rectangular texture/ comparison
sampler[1,2]DArray	1D or 2D array texture
sampler[1,2]DArrayShadow	1D or 2D array depth texture/comparison
samplerBuffer	buffer texture
sampler2DMS	2D multi-sample texture
sampler2DMSArray	2D multi-sample array texture
samplerCubeArray	cube map array texture
samplerCubeArrayShadow	cube map array depth texture with comparison

Integer Sampler Types (Opaque)

isampler[1,2,3]D	integer 1D, 2D, or 3D texture
isamplerCube	integer cube mapped texture
isampler2DRect	int. 2D rectangular texture
isampler[1,2]DArray	integer 1D, 2D array texture
isamplerBuffer	integer buffer texture
isampler2DMS	int. 2D multi-sample texture
isampler2DMSArray	int. 2D multi-sample array tex.
isamplerCubeArray	int. cube map array texture

Unsigned Integer Sampler Types (Opaque)

usampler[1,2,3]D	uint 1D, 2D, or 3D texture
usamplerCube	uint cube mapped texture
usampler2DRect	uint rectangular texture
usampler[1,2]DArray	1D or 2D array texture
usamplerBuffer	uint buffer texture
usampler2DMS	uint 2D multi-sample texture
usampler2DMSArray	uint 2D multi-sample array tex.
usamplerCubeArray	uint cube map array texture

Implicit Conversions (All others must use constructors)

int	->	uint
int, uint	->	float
int, uint, float	->	double
ivec2|3|4	->	uvec2|3|4
ivec2|3|4	->	vec2|3|4
uvec2|3|4	->	vec2|3|4
vec2|3|4	->	dvec2|3|4
ivec2|3|4	->	dvec2|3|4
uvec2|3|4	->	dvec2|3|4
mat2|3|4	->	dmat2|3|4
mat2x3|2x4	->	dmat2x3|2x4
mat3x2|3x4	->	dmat3x2|3x4
mat4x2|4x3	->	dmat4x2|4x3

Aggregation of Basic Types

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

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

Blocks	**in/out/uniform** *block-name* {
	// interface matching by block name
	optionally-qualified members
	} *instance-name*[];
	// optional instance name, optionally an array

Preprocessor [3.3]

Preprocessor Operators

Preprocessor operators follow C++ standards. Expressions are evaluated according to the behavior of the host processor, not the processor targeted by the shader.

#version 410 #version 410 *profile*	"#version 410" is required in shaders using version 4.10 of the language. Use *profile* to indicate core or compatibilty. If no *profile* specified, the default is core.
#extension *extension_name* : *behavior* #extension all : *behavior*	• *behavior*: require, enable, warn, disable • *extension_name:* the extension supported by the compiler, or "all"

Preprocessor Directives

Each number sign (#) can be preceded in its line only by spaces or horizontal tabs.

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

Predefined Macros

__LINE__ __FILE__	Decimal integer constants. FILE says which source string number is being processed, or the path of the string if the string was an included string
GL_compatibility_profile	Integer 1 if the implementation supports the compatibility profile
__VERSION__	Decimal integer, e.g.: 410

Qualifiers

Storage Qualifiers [4.3]

Declarations may have one storage qualifier.

none	(default) local read/write memory, or input parameter
const	compile-time constant, or read-only function parameter
in	linkage into shader from previous stage
centroid in	linkage w/centroid based interpolation
sample in	input linkage w/per-sample interpolation
out	linkage out of a shader to next stage
centroid out	linkage w/centroid based interpolation
sample out	output linkage w/per-sample interpolation
attribute ‡	linkage between a vertex shader and OpenGL for per-vertex data
uniform	linkage between a shader, OpenGL, and the application
varying ‡ **centroid varying** ‡	linkage between a vertex shader and a fragment shader for interpolated data
patch in	tessellation eval. shader input
patch out	tessellation control shader output

‡ Qualifier is deprecated but not removed from core specification.

Uniform Qualifiers [4.3.5]

Declare global variables with same values across entire primitive processed. Examples:

uniform vec4 lightPosition;
uniform vec3 color = vec3(0.7, 0.7, 0.2);

Layout Qualifiers [4.3.8]

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

Input Layout Qualifiers

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

For tessellation evaluation shaders:
triangles, quads, equal_spacing, isolines, fractional_{even,odd}_spacing, cw, ccw, point_mode

For geometry shader inputs:
points, lines, {lines,triangles}_adjacency, triangles, invocations = *integer-constant*

For fragment shaders only for redeclaring built-in variable gl_FragCoord:
origin_upper_left, pixel_center_integer

Output Layout Qualifiers

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

For tessellation control shaders:
vertices = *integer-constant*

For geometry shader outputs:
points, line_strip, triangle_strip, max_vertices = *integer-constant,* stream = *integer-constant*

(Qualifiers Continue >)

Qualifiers (continued)

For fragment shaders:
index = *integer-constant*

Uniform-Block Layout Qualifiers

Layout qualifier identifiers for uniform blocks:
shared, packed, std140, {row, column}_major

Interpolation Qualifier [4.3.9]

Qualify outputs from vertex shader and inputs to fragment shader.

smooth	perspective correct interpolation
flat	no interpolation
noperspective	linear interpolation

The following predeclared variables can be redeclared with an interpolation qualifier:

Vertex language:	**Fragment language:**
gl_FrontColor	gl_Color
gl_BackColor	gl_SecondaryColor
gl_FrontSecondaryColor	
gl_BackSecondaryColor	

Parameter Qualifiers [4.4]

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

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

Precision Qualifiers [4.5]

Precision qualifiers have no effect on precision; they aid code portability with OpenGL ES:
highp, mediump, lowp

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

Precise Qualifier [4.7]

Ensures that operations are executed in stated order with operator consistency. Requires two identical multiplies, followed by an add.

precise out **vec4** Position = a * b + c * d;

Order of Qualification [4.8]

When multiple qualifications are present, they must follow this strict order:

precise invariant interpolation storage precision
storage parameter precision

Operations and Constructors

Vector & Matrix Constructors [5.4.2]

```
mat2(vec2, vec2);              // 1 col./arg.
mat2x3(vec2, float, vec2, float);  // col. 2
dmat2(dvec2, dvec2);           // 1 col./arg.
dmat3(dvec3, dvec3, dvec3);    // 1 col./arg.
```

Structure Constructor Example [5.4.3]

```
struct light {members; };
light lightVar = light(3.0, vec3(1.0, 2.0, 3.0));
```

Array Constructor Example [5.4.4]

```
const float c[3] = float[3](5.0, b + 1.0, 1.1);
```

Matrix Component Examples [5.6]

Examples of access components of a matrix with array subscripting syntax:

```
mat4 m;          // m is a matrix
m[1] = vec4(2.0); // sets 2nd col. 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 col. 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 +/- matrix comp.-wise
m = m * m;       // linear algebraic multiply
f = dot(v, v);   // vector dot product
v = cross(v, v); // vector cross product
```

Structure & Array Operations [5.7]

Select structure fields, length() method of an array using the period (.) operator. Other operators:

.	field or method selector
== !=	equality
=	assignment
[ ]	indexing (arrays only)

Array elements are accessed using the array subscript operator ([ ]), e.g.:

diffuseColor += lightIntensity[3]*NdotL;

Statements and Structure

Iteration and Jumps [6.3-4]

Function	call by value-return

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

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

Entry	void main()
Jump	break, continue, return (There is no 'goto')
Exit	return in main() discard // Fragment shader only

Subroutines [6.1.2]

Declare types with the **subroutine** keyword:

```
subroutine returnType
    subroutineTypeName(type0 arg0,
    type1 arg1, ..., typen argn);
```

Associate functions with subroutine types of matching declarations by defining the functions with the subroutine keyword and a list of subroutine types the function matches:

```
subroutine(subroutineTypeName0, ...,
    subroutineTypeNameN)
returnType functionName(type0 arg0,
    type1 arg1, ..., typen argn){ ... }
    // function body
```

Declare subroutine type variables with a specific subroutine type in a subroutine uniform variable declaration:

```
subroutine uniform subroutineTypeName
    subroutineVarName;
```

Subroutine type variables are assigned to functions through the **UniformSubroutinesuiv** command in the OpenGL API.

Operators & Expressions [5.1]

Numbered in order of precedence. Relational and equality operators > < <= >= == != evaluate to Boolean. Compare vectors component-wise with functions such as lessThan(), equal(), etc.

1.	**( )**	parenthetical grouping
2.	**[ ]** **( )** **.** **++ --**	array subscript function call & constructor structure field or method selector, swizzler postfix increment and decrement
3.	**++ --** **+ - ~ !**	prefix increment and decrement unary
4.	*** / %**	multiplicative
5.	**+ -**	additive
6.	**<< >>**	bit-wise shift
7.	**< > <= >=**	relational
8.	**== !=**	equality
9.	**&**	bit-wise and
10.	**^**	bit-wise exclusive or
11.	**|**	bit-wise inclusive or
12.	**&&**	logical and
13.	**^^**	logical exclusive or
14.	**||**	logical inclusive or
15.	**? :**	selects an entire operand. Use **mix**() to select indiv. components of vectors.
16.	**= += -=** ***= /=** **%= <<= >>=** **&= ^= |=**	assignment arithmetic assignments
17.	**,**	sequence

Vector Components [5.5]

In addition to array numeric subscript syntax, names of vector components denoted by a single letter. Components can be swizzled and replicated.

{x, y, z, w}	Vectors representing points or normals
{r, g, b, a}	Vectors representing colors
{s, t, p, q}	Vectors representing texture coordinates

Built-In Variables [7]

Shaders communicate with fixed-function OpenGL pipeline stages and other shader executables through built-in input and output variables. Redeclare matching subsets of these variables and blocks to establish matching interfaces when using multiple programs.

Vertex Language

Inputs:

```
in int   gl_VertexID;
in int   gl_InstanceID;
in vec4  gl_Color;
in vec4  gl_SecondaryColor;
in vec3  gl_Normal;
in vec4  gl_Vertex;
in vec4  gl_MultiTexCoordn          // n is 0...7
in float gl_FogCoord;
```

Outputs:

```
out gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    vec4  gl_ClipVertex;
    vec4  gl_FrontColor;
    vec4  gl_BackColor;
    vec4  gl_FrontSecondaryColor;
    vec4  gl_BackSecondaryColor;
    vec4  gl_TexCoord[];
    float gl_FogFragCoord;
};
```

Tessellation Control Language

Inputs:

```
in gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    (... plus deprecated Vertex Language Outputs)
} gl_in[gl_MaxPatchVertices];
```

Tessellation Control (continued)

Inputs (continued):

```
in int  gl_PatchVerticesIn;
in int  gl_PrimitiveID;
in int  gl_InvocationID;
```

Outputs:

```
out gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    (... plus deprecated Vertex Language Outputs)
} gl_out[];

patch out float gl_TessLevelOuter[4];
patch out float gl_TessLevelInner[2];
```

Tessellation Evaluation Language

Inputs:

```
in gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    (... plus deprecated Vertex Language Outputs)
} gl_in[gl_MaxPatchVertices];

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

Outputs:

```
out gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    (... plus deprecated Vertex Language Outputs)
};
```

Geometry Language

Inputs:

```
in gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    (... plus deprecated Vertex Language Outputs)
} gl_in[];

in int gl_PrimitiveIDIn;
in int gl_InvocationID;
```

Outputs:

```
out gl_PerVertex {
    vec4  gl_Position;
    float gl_PointSize;
    float gl_ClipDistance[];
    (... plus deprecated Vertex Language Outputs)
};

out int gl_PrimitiveID;
out int gl_Layer;
out int gl_ViewportIndex;
```

Fragment Language

Inputs:

```
in vec4  gl_FragCoord;
in bool  gl_FrontFacing;
in float gl_ClipDistance[];
in vec2  gl_PointCoord;
in int   gl_PrimitiveID;
in int   gl_SampleID;
in vec2  gl_SamplePosition;
in float gl_FogFragCoord;
in vec4  gl_TexCoord[];
in vec4  gl_Color;
in vec4  gl_SecondaryColor;
```

Outputs:

```
out  vec4 gl_FragColor;
out  vec4 gl_FragData[gl_MaxDrawBuffers];
out  float gl_FragDepth;
out  int  gl_SampleMask[];
```

Built-In Constants [7.3]

The following built-in constants with minimum values are provided to all shaders. The actual values used are implementation- dependent, but must be at least the value shown.

```
const int gl_MaxTextureUnits = 2;
const int gl_MaxTextureCoords = 8;
const int gl_MaxClipPlanes = 8;
const int gl_MaxVertexAttribs = 16;
const int gl_MaxVertexUniformComponents = 1024;
const int gl_MaxVaryingFloats = 60;
const int gl_MaxVaryingComponents = 60;
const int gl_MaxVertexOutputComponents = 64;
const int gl_MaxGeometryInputComponents = 64;
const int gl_MaxGeometryOutputComponents = 128;
const int gl_MaxFragmentInputComponents = 128;
const int gl_MaxVertexTextureImageUnits = 16;
const int gl_MaxCombinedTextureImageUnits = 80;
const int gl_MaxTextureImageUnits = 16;
const int gl_MaxFragmentUniformComponents = 1024;
const int gl_MaxDrawBuffers = 8;
const int gl_MaxClipDistances = 8;
const int gl_MaxGeometryTextureImageUnits = 16;
const int gl_MaxGeometryOutputVertices = 256;
const int gl_MaxGeometryTotalOutputComponents = 1024;
const int gl_MaxGeometryUniformComponents = 1024;
const int gl_MaxGeometryVaryingComponents = 64;
const int gl_MaxTessControlInputComponents = 128;
const int gl_MaxTessControlOutputComponents = 128;
const int gl_MaxTessControlTextureImageUnits = 16;
const int gl_MaxTessControlUniformComponents = 1024;
const int gl_MaxTessControlTotalOutputComponents = 4096;
const int gl_MaxTessEvaluationInputComponents = 128;
const int gl_MaxTessEvaluationOutputComponents = 128;
const int gl_MaxTessEvaluationTextureImageUnits = 16;
const int gl_MaxTessEvaluationUniformComponents = 1024;
const int gl_MaxTessPatchComponents = 120;
const int gl_MaxPatchVertices = 32;
const int gl_MaxTessGenLevel = 64;
const int gl_MaxViewports = 16;
const int gl_MaxVertexUniformVectors = 256;
const int gl_MaxFragmentUniformVectors = 256;
const int gl_MaxVaryingVectors = 15;
```

Built-In Functions

Angle & Trig. Functions [8.1]

Functions will not result in a divide-by-zero error. If the divisor of a ratio is 0, then results will be undefined. Component-wise operation. Parameters specified as *angle* are in units of radians. Tf=float, vec*n*.

Tf **radians**(Tf *degrees*)	degrees to radians
Tf **degrees**(Tf *radians*)	radians to degrees
Tf **sin**(Tf *angle*)	sine
Tf **cos**(Tf *angle*)	cosine
Tf **tan**(Tf *angle*)	tangent
Tf **asin**(Tf *x*)	arc sine
Tf **acos**(Tf *x*)	arc cosine
Tf **atan**(Tf *y*, Tf *x*) Tf **atan**(Tf *y_over_x*)	arc tangent
Tf **sinh**(Tf *x*)	hyperbolic sine
Tf **cosh**(Tf *x*)	hyperbolic cosine
Tf **tanh**(Tf *x*)	hyperbolic tangent
Tf **asinh**(Tf *x*)	hyperbolic sine
Tf **acosh**(Tf *x*)	hyperbolic cosine
Tf **atanh**(Tf *x*)	hyperbolic tangent

Exponential Functions [8.2]

Component-wise operation. Tf=float, vec*n*. Tfd= float, vec*n*, double, dvec*n*.

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

Common Functions [8.3]

Component-wise operation. Tf=float, vec*n*. Tfd= float, vec*n*, double, dvec*n*.

Tfd **abs**(Tfd *x*) Ti **abs**(Ti *x*)	absolute value
Tfd **sign**(Tfd *x*) Ti **sign**(Ti *x*)	returns -1.0, 0.0, or 1.0
Tfd **floor**(Tfd *x*)	nearest integer <= *x*
Tfd **trunc**(Tfd *x*)	nearest integer with absolute value <= absolute value of *x*
Tfd **round**(Tfd *x*)	nearest integer, implementation-dependent rounding mode
Tfd **roundEven**(Tfd *x*)	nearest integer, 0.5 rounds to nearest even integer
Tfd **ceil**(Tfd *x*)	nearest integer >= *x*
Tfd **fract**(Tfd *x*)	*x* - floor(*x*)
Tfd **mod**(Tfd *x*, Tfd *y*) Tf **mod**(Tf *x*, float *y*) Td **mod**(Td *x*, double *y*)	modulus
Tfd **modf**(Tfd *x*, out Tfd *i*)	separate integer and fractional parts
Tfd **min**(Tfd *x*, Tfd *y*) Tf **min**(Tf *x*, float *y*) Td **min**(Td *x*, double *y*) Tiu **min**(Tiu *x*, Tiu *y*) Ti **min**(Ti *x*, int *y*) Tu **min**(Tu *x*, uint *y*)	minimum value
Tfd **max**(Tfd *x*, Tfd *y*) Tf **max**(Tf *x*, float *y*) Td **max**(Td *x*, double *y*) Tiu **max**(Tiu *x*, Tiu *y*) Ti **max**(Ti *x*, int *y*) Tu **max**(Tu *x*, uint *y*)	maximum value

Common Functions (continued)

Tfd **mix**(Tfd *x*, Tfd *y*, Tfd *a*) Tf **mix**(Tf *x*, Tf *y*, float *a*) Td **mix**(Td *x*, Td *y*, double *a*)	linear blend of *x* and *y*
Tfd **mix**(Tfd *x*, Tfd *y*, Tb *a*)	true if comps. in *a* select comps. from *y*, else from x
Tfd **step**(Tfd *edge*, Tfd *x*) Tf **step**(float *edge*, Tf *x*) Td **step**(double *edge*, Td *x*)	0.0 if *x* < *edge*, else 1.0
Tb **isnan**(Tfd *x*)	true if *x* is NaN
Tb **isinf**(Tfd *x*)	true if *x* is positive or negative infinity
Tfd **clamp**(Tfd *x*, Tfd *minVal*, Tfd *maxVal*) Tf **clamp**(Tf *x*, float *minVal*, float *maxVal*) Td **clamp**(Td *x*, double *minVal*, double *maxVal*) Tiu **clamp**(Tiu *x*, Tiu *minVal*, Tiu *maxVal*) Ti **clamp**(Ti *x*, int *minVal*, int *maxVal*) Tu **clamp**(Tu *x*, uint *minVal*, uint *maxVal*)	min(max(*x*, *minVal*), *maxVal*)
Tfd **smoothstep**(Tfd *edge0*, Tfd *edge1*, T *x*) Tf **smoothstep**(float *edge0*, float *edge1*, Tf *x*) Td **smoothstep**(double *edge0*, double *edge1*, Td *x*)	clip and smooth
Ti **floatBitsToInt**(Tf *value*) Tu **floatBitsToInt**(Tf *value*)	Returns signed int or uint value representing the encoding of a floating-point value.
Tf **intBitsToFloat**(Tiu *value*)	Returns floating-point value of a signed int or uint encoding of a floating-point value.
Tfd **fma**(Tfd *a*, Tfd *b*, Tfd *c*)	Computes and returns a*b + c. Treated as a single operation when using **precise**.
Tfd **frexp**(Tfd *x*, out Ti *exp*)	Splits *x* into a floating-point significand in the range [0.5, 1.0) and an int. exp. of 2.
Tfd **ldexp**(Tfd *x*, in Ti *exp*)	Builds a floating-point number from *x* and the corresponding integral exponent of 2 in *exp*.

Floating-Point Pack/Unpack [8.4]

These do not operate component-wise.

uint **packUnorm2x16**(vec2 *v*) uint **packUnorm4x8**(vec4 *v*) uint **packSnorm4x8**(vec4 *v*)	Converts each comp. of *v* into 8- or 16-bit ints, packs results into the returned 32-bit unsigned integer.
vec2 **unpackUnorm2x16** (uint *p*) vec4 **unpackUnorm4x8** (uint *p*) vec4 **unpackSnorm4x8** (uint *p*)	Unpacks 32-bit *p* into two 16-bit uints, four 8-bit uints, or signed ints. Then converts each component to a normalized float to generate a 2- or 4-component vector.
double **packDouble2x32** (uvec2 *v*)	Packs components of *v* into a 64-bit value and returns a double-precision value.
uvec2 **unpackDouble2x32** (double *v*)	Returns a 2-component vector representation of *v*.

Geometric Functions [8.5]

These functions operate on vectors as vectors, not component-wise. Tf=float, vec*n*. Td =double, dvec*n*. Tfd= float, vec*n*, double, dvec*n*.

float **length**(Tf *x*) double **length**(Td *x*)	length of vector
float **distance**(Tf *p0*, Tf *p1*) double **distance**(Td *p0*, Td *p1*)	distance between points
float **dot**(Tf *x*, Tf *y*) double **dot**(Td *x*, Td *y*)	dot product
vec3 **cross**(vec3 *x*, vec3 *y*) dvec3 **cross**(dvec3 *x*, dvec3 *y*)	cross product

Type Abbreviations for Built-in Functions:

Tf=float, vec*n*. Td =double, dvec*n*. Tfd= float, vec*n*, double, dvec*n*. Tb=bvec*n*, bool. Tvec=vec*n*, uvec*n*, ivec*n*. Tu=uint, uvec*n*. Ti=int, ivec*n*. Tiu=int, ivec*n*, uint, uvec*n*.

Use of T*n* or T*nn* within each function call must be the same. In vector types, *n* is 2, 3, or 4.

Geometric Functions (continued)

Tf **normalize**(Tf *x*) Td **normalize**(Td *x*)	normalize vector to length 1
vec4 **ftransform**( )	invariant vertex transform
Tfd **faceforward**(Tfd *N*, Tfd *I*, Tfd *Nref*)	returns *N* if dot(*Nref*, *I*) < 0, else -*N*
Tfd **reflect**(Tfd *I*, Tfd *N*)	reflection direction *I* - 2 * dot(*N*,*I*) * *N*
Tfd **refract**(Tfd *I*, Tfd *N*, float *eta*)	refraction vector

Matrix Functions [8.6]

For the matrix functions, type *mat* is used in the single-precision floating point functions, and type *dmat* is used in the double-precision floating point functions. *N* and *M* are 1, 2, 3, 4.

mat **matrixCompMult**(mat *x*, mat *y*) dmat **matrixCompMult**(dmat *x*, dmat *y*)	component-wise multiply
mat*N* **outerProduct**(vec*N* *c*, vec*N* *r*) dmat*N* **outerProduct**(dvec*N* *c*, dvec*N* *r*)	outer product (where *N* != *M*)
mat*NxM* **outerProduct**(vec*M* *c*, vec*N* *r*) dmat*NxM* **outerProduct**(dvec*M* *c*, dvec*N* *r*)	outer product
mat*N* **transpose**(mat*N* *m*) dmat*N* **transpose**(dmat*N* *m*)	transpose
mat*NxM* **transpose**(mat*MxN* *m*) dmat*NxM* **transpose**(dmat*MxN* *m*)	transpose (where *N* != *M*)
float **determinant**(mat*N* *m*) double **determinant**(dmat*N* *m*)	determinant
mat*N* **inverse**(mat*N* *m*) dmat*N* **inverse**(dmat*N* *m*)	inverse

Vector Relational Functions [8.7]

Compare *x* and *y* component-wise. Sizes of the input and return vectors for any particular call must match. Tvec=vec*n*, uvec*n*, ivec*n*.

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

Integer Functions [8.8]

Component-wise operation. Tu=uint, uvec*n*. Ti=int, ivec*n*. Tiu=int, ivec*n*, uint, uvec*n*.

Tu **uaddCarry**(Tu *x*, Tu *y*, out Tu *carry*)	Adds 32-bit uintx and *y*, returning the sum modulo 2^{32}.
Tu **usubBorrow**(Tu *x*, Tu *y*, out Tu *borrow*)	Subtracts *y* from *x*, returning the difference if non-negative, otherwise 2^{32} plus the difference.

Integer Functions (continued)

void **umulExtended**(Tu *x*, Tu *y*, out Tu *msb*, out Tu *lsb*) void **imulExtended**(Ti *x*, Ti *y*, out Ti *msb*, out Ti *lsb*)	Multiplies 32-bit integers *x* and *y*, producing a 64-bit result.
Tiu **bitfieldExtract**(Tiu *value*, int *offset*, int *bits*)	Extracts bits [*offset*, *offset* + *bits* - 1] from *value*, returns them in the least significant bits of the result.
Tiu **bitfieldInsert**(Tiu *base*, Tiu *insert*, int *offset*,int *bits*)	Returns the insertion the *bits* least-significant bits of *insert* into *base*.
Tiu **bitfieldReverse**(Tiu *value*)	Returns the reversal of the bits of *value*.
Ti **bitCount**(Tiu *value*)	Returns the number of bits set to 1.
Ti **findLSB**(Tiu *value*)	Returns bit number of least significant bit.
Ti **findMSB**(Tiu *value*)	Returns bit number of most significant bit.

Texture Lookup Functions [8.9]

See next page

Fragment Processing Functions [8.10]

Available only in fragment shaders. Tf=float, vec*n*.

Derivative functions

Tf **dFdx**(Tf *p*)	derivative in *x*
Tf **dFdy**(Tf *p*)	derivative in *y*
Tf **fwidth**(Tf *p*)	sum of absolute derivative in *x* and *y*

Interpolation functions

Tf **interpolateAtCentroid**(Tf *interpolant*)	Return value of *interpolant* sampled inside pixel and the primitive.
Tf **interpolateAtSample**(Tf *interpolant*, int *sample*)	Return value of *interpolant* at the location of sample number *sample*.
Tf **interpolateAtOffset**(Tf *interpolant*, vec2 *offset*)	Return value of *interpolant* sampled at fixed offset *offset* pixel center.

Noise Functions [8.11]

Returns noise value. Available to fragment, geometry, and vertex shaders.

float **noise1**(Tf *x*)	
vec*n* **noise*n***(Tf *x*)	where *n* is 2, 3, or 4

Geometry Shader Functions [8.12]

Only available in geometry shaders.

void **EmitStreamVertex**(int *stream*)	Emits values of output variables to the current output primitive stream *stream*.
void **EndStreamPrimitive**(int *stream*)	Completes current output primitive stream *stream* and starts a new one.
void **EmitVertex**()	Emits values of output variables to the current output primitive.
void **EndPrimitive**()	Completes output primitive and starts a new one.

Shader Invocation Control [8.13]

Controls execution order of shader invocations. Available only to tessellation control shaders.

void **barrier**()	Synchronizes across shader invocations.

Texture Functions [8.9]

Available to vertex, geometry, and fragment shaders. gvec4=vec4, ivec4, uvec4. gsampler* =sampler*, isampler*, usampler*.

Texture Query [8.9.1]

int **textureSize**(gsampler1D *sampler*, int *lod*)
ivec2 **textureSize**(gsampler2D *sampler*, int *lod*)
ivec3 **textureSize**(gsampler3D *sampler*, int *lod*)
ivec2 **textureSize**(gsamplerCube *sampler*, int *lod*)
int **textureSize**(sampler1DShadow *sampler*, int *lod*)
ivec2 **textureSize**(sampler2DShadow *sampler*, int *lod*)
ivec2 **textureSize**(samplerCubeShadow *sampler*, int *lod*)
ivec3 **textureSize**(samplerCubeArray *sampler*, int *lod*)
ivec3 **textureSize**(samplerCubeArrayShadow *sampler*, int *lod*)
ivec2 **textureSize**(gsampler2DRect *sampler*)
ivec2 **textureSize**(sampler2DRectShadow *sampler*)
ivec2 **textureSize**(gsampler1DArray *sampler*, int *lod*)
ivec3 **textureSize**(gsampler2DArray *sampler*, int *lod*)
ivec2 **textureSize**(sampler1DArrayShadow *sampler*, int *lod*)
ivec3 **textureSize**(sampler2DArrayShadow *sampler*, int *lod*)
int **textureSize**(gsamplerBuffer *sampler*)
ivec2 **textureSize**(gsampler2DMS *sampler*)
ivec2 **textureSize**(gsampler2DMSArray *sampler*)

vec2 **textureQueryLod**(gsampler1D *sampler*, float *P*)
vec2 **textureQueryLod**(gsampler2D *sampler*, vec2 *P*)
vec2 **textureQueryLod**(gsampler3D *sampler*, vec3 *P*)
vec2 **textureQueryLod**(gsamplerCube *sampler*, vec3 *P*)
vec2 **textureQueryLod**(gsampler1DArray *sampler*, float *P*)
vec2 **textureQueryLod**(gsampler2DArray *sampler*, vec2 *P*)
vec2 **textureQueryLod**(gsamplerCubeArray *sampler*, vec3 *P*)
vec2 **textureQueryLod**(sampler1DShadow *sampler*, float *P*)
vec2 **textureQueryLod**(sampler2DShadow *sampler*, vec2 *P*)
vec2 **textureQueryLod**(samplerCubeShadow *sampler*, vec3 *P*)
vec2 **textureQueryLod**(sampler1DArrayShadow *sampler*, float *P*)
vec2 **textureQueryLod**(sampler2DArrayShadow *sampler*, vec2 *P*)
vec2 **textureQueryLod**(samplerCubeArrayShadow *sampler*, vec3 *P*)

Texel Lookup Functions [8.9.2]

Use texture coordinate *P* to do a lookup in the texture bound to *sampler*.

gvec4 **texture**(gsampler1D *sampler*, float *P* [, float *bias*])
gvec4 **texture**(gsampler2D *sampler*, vec2 *P* [, float *bias*])
gvec4 **texture**(gsampler3D *sampler*, vec3 *P* [, float *bias*])
gvec4 **texture**(gsamplerCube *sampler*, vec3 *P* [, float *bias*])
float **texture**(sampler{1D,2D}Shadow *sampler*, vec3 *P* [, float *bias*])
float **texture**(samplerCubeShadow *sampler*, vec4 *P* [, float *bias*])
gvec4 **texture**(gsampler1DArray *sampler*, vec2 *P* [, float *bias*])
gvec4 **texture**(gsampler2DArray *sampler*, vec3 *P* [, float *bias*])
gvec4 **texture**(gsamplerCubeArray *sampler*, vec4 *P* [, float *bias*])
float **texture**(sampler1DArrayShadow *sampler*, vec3 *P* [, float *bias*])
float **texture**(sampler2DArrayShadow *sampler*, vec4 *P*)
gvec4 **texture**(gsampler2DRect *sampler*, vec2 *P*)
float **texture**(sampler2DRectShadow *sampler*, vec3 *P*)
float **texture**(gsamplerCubeArrayShadow *sampler*, vec4 *P*, float *compare*)

Texture lookup with projection.

gvec4 **textureProj**(gsampler1D *sampler*, vec{2,4} *P* [, float *bias*])
gvec4 **textureProj**(gsampler2D *sampler*, vec{3,4} *P* [, float *bias*])
gvec4 **textureProj**(gsampler3D *sampler*, vec4 *P* [, float *bias*])
float **textureProj**(sampler{1D,2D}Shadow *sampler*, vec4 *P* [, float *bias*])
gvec4 **textureProj**(gsampler2DRect *sampler*, vec{3,4} *P*)
float **textureProj**(sampler2DRectShadow *sampler*, vec4 *P*)

Texture lookup as in **texture** but with explicit LOD.

gvec4 **textureLod**(gsampler1D *sampler*, float *P*, float *lod*)
gvec4 **textureLod**(gsampler2D *sampler*, vec2 *P*, float *lod*)
gvec4 **textureLod**(gsampler3D *sampler*, vec3 *P*, float *lod*)
gvec4 **textureLod**(gsamplerCube *sampler*, vec3 *P*, float *lod*)
float **textureLod**(sampler{1D,2D}Shadow *sampler*, vec3 *P*, float *lod*)
gvec4 **textureLod**(gsampler1DArray *sampler*, vec2 *P*, float *lod*)
gvec4 **textureLod**(gsampler2DArray *sampler*, vec3 *P*, float *lod*)
float **textureLod**(sampler1DArrayShadow *sampler*, vec3 *P*, float *lod*)
gvec4 **textureLod**(gsamplerCubeArray *sampler*, vec4 *P*, float *lod*)

Offset added before texture lookup as in **texture**.

gvec4 **textureOffset**(gsampler1D *sampler*, float *P*, int *offset* [, float *bias*])
gvec4 **textureOffset**(gsampler2D *sampler*, vec2 *P*, ivec2 *offset* [, float *bias*])
gvec4 **textureOffset**(gsampler3D *sampler*, vec3 *P*, ivec3 *offset* [, float *bias*])
gvec4 **textureOffset**(gsampler2DRect *sampler*, vec2 *P*, ivec2 *offset*)
float **textureOffset**(sampler2DRectShadow *sampler*, vec3 *P*, ivec2 *offset*)
float **textureOffset**(sampler1DShadow *sampler*, vec3 *P*, int *offset* [, float *bias*])
float **textureOffset**(sampler2DShadow *sampler*, vec3 *P*, ivec2 *offset* [, float *bias*])
gvec4 **textureOffset**(gsampler1DArray *sampler*, vec2 *P*, int *offset* [, float *bias*])
gvec4 **textureOffset**(gsampler2DArray *sampler*, vec3 *P*, ivec2 *offset* [, float *bias*])
float **textureOffset**(sampler1DArrayShadow *sampler*, vec3 *P*, int *offset* [, float *bias*])

Use integer texture coordinate *P* to lookup a single texel from *sampler*.

gvec4 **texelFetch**(gsampler1D *sampler*, int *P*, int *lod*)
gvec4 **texelFetch**(gsampler2D *sampler*, ivec2 *P*, int *lod*)
gvec4 **texelFetch**(gsampler3D *sampler*, ivec3 *P*, int *lod*)
gvec4 **texelFetch**(gsampler2DRect *sampler*, ivec2 *P*)
gvec4 **texelFetch**(gsampler1DArray *sampler*, ivec2 *P*, int *lod*)
gvec4 **texelFetch**(gsampler2DArray *sampler*, ivec3 *P*, int *lod*)
gvec4 **texelFetch**(gsamplerBuffer *sampler*, int *P*)
gvec4 **texelFetch**(gsampler2DMS *sampler*, ivec2 *P*, int *sample*)
gvec4 **texelFetch**(gsampler2DMSArray *sampler*, ivec3 *P*, int *sample*)

Fetch single texel as in **texelFetch** offset by *offset* as described in **textureOffset**.

gvec4 **texelFetchOffset**(gsampler1D *sampler*, int *P*, int *lod*, int *offset*)
gvec4 **texelFetchOffset**(gsampler2D *sampler*, ivec2 *P*, int *lod*, ivec2 *offset*)
gvec4 **texelFetchOffset**(gsampler3D *sampler*, ivec3 *P*, int *lod*, ivec3 *offset*)
gvec4 **texelFetchOffset**(gsampler2DRect *sampler*, ivec2 *P*, ivec2 *offset*)
gvec4 **texelFetchOffset**(gsampler1DArray *sampler*, ivec2 *P*, int *lod*, int *offset*)
gvec4 **texelFetchOffset**(gsampler2DArray *sampler*, ivec3 *P*, int *lod*, ivec2 *offset*)

Projective lookup as described in **textureProj** offset by *offset* as described in **textureOffset**.

gvec4 **textureProjOffset**(gsampler1D *sampler*, vec{2,4} *P*, int *offset* [, float *bias*])
gvec4 **textureProjOffset**(gsampler2D *sampler*, vec{3,4} *P*, ivec2 *offset* [, float *bias*])
gvec4 **textureProjOffset**(gsampler3D *sampler*, vec4 *P*, ivec3 *offset* [, float *bias*])
gvec4 **textureProjOffset**(gsampler2DRect *sampler*, vec{3,4} *P*, ivec2 *offset*)
float **textureProjOffset**(sampler2DRectShadow *sampler*, vec4 *P*, ivec2 *offset*)
float **textureProjOffset**(sampler1DShadow *sampler*, vec4 *P*, int offset [, float *bias*])
float **textureProjOffset**(sampler2DShadow *sampler*, vec4 *P*, ivec2 *offset* [, float *bias*])

Offset texture lookup with explicit LOD. *See textureLod and textureOffset.*

gvec4 **textureLodOffset**(gsampler1D *sampler*, float *P*, float *lod*, int *offset*)
gvec4 **textureLodOffset**(gsampler2D *sampler*, vec2 *P*, float *lod*, ivec2 *offset*)
gvec4 **textureLodOffset**(gsampler3D *sampler*, vec3 *P*, float *lod*, ivec3 *offset*)
float **textureLodOffset**(sampler1DShadow *sampler*, vec3 *P*, float *lod*, int *offset*)
float **textureLodOffset**(sampler2DShadow *sampler*, vec3 *P*, float *lod*, ivec2 *offset*)
gvec4 **textureLodOffset**(gsampler1DArray *sampler*, vec2 *P*, float *lod*, int *offset*)
gvec4 **textureLodOffset**(gsampler2DArray *sampler*, vec3 *P*, float *lod*, ivec2 *offset*)
float **textureLodOffset**(sampler1DArrayShadow *sampler*, vec3 *P*, float *lod*, int *offset*)

Projective texture lookup with explicit LOD. *See textureLod and textureOffset.*

gvec4 **textureProjLod**(gsampler1D *sampler*, vec{2,4} *P*, float *lod*)
gvec4 **textureProjLod**(gsampler2D *sampler*, vec{3,4} *P*, float *lod*)
gvec4 **textureProjLod**(gsampler3D *sampler*, vec4 *P*, float *lod*)
float **textureProjLod**(sampler{1,2}DShadow *sampler*, vec4 *P*, float *lod*)

Offset projective texture lookup with explicit LOD. *See textureProj, textureLod, and textureOffset.*

gvec4 **textureProjLodOffset**(gsampler1D *sampler*, vec{2,4} *P*, float *lod*, int *offset*)
gvec4 **textureProjLodOffset**(gsampler2D *sampler*, vec{3,4} *P*, float *lod*, ivec2 *offset*)
gvec4 **textureProjLodOffset**(gsampler3D *sampler*, vec4 *P*, float *lod*, ivec3 *offset*)
float **textureProjLodOffset**(sampler1DShadow *sampler*, vec4 *P*, float *lod*, int *offset*)
float **textureProjLodOffset**(sampler2DShadow *sampler*, vec4 *P*, float *lod*, ivec2 *offset*)

Texture lookup as in **texture** but with explicit gradients.

gvec4 **textureGrad**(gsampler1D *sampler*, float *P*, float *dPdx*, float *dPdy*)
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**(gsampler2DRect *sampler*, vec2 *P*, vec2 *dPdx*, vec2 *dPdy*)
float **textureGrad**(sampler2DRectShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*)
float **textureGrad**(sampler1DShadow *sampler*, vec3 *P*, float *dPdx*, float *dPdy*)
float **textureGrad**(sampler2DShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*)
gvec4 **textureGrad**(gsampler1DArray *sampler*, vec2 *P*, float *dPdx*, float *dPdy*)
gvec4 **textureGrad**(gsampler2DArray *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*)
float **textureGrad**(sampler1DArrayShadow *sampler*, vec3 *P*, float *dPdx*, float *dPdy*)
float **textureGrad**(sampler2DArrayShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*)
gvec4 **textureGrad**(gsamplerCubeArray *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*)

Texture lookup with both explicit gradient and offset, as described in **textureGrad** and **textureOffset.**

gvec4 **textureGradOffset**(gsampler1D *sampler*, float *P*, float *dPdx*, float *dPdy*, int *offset*)
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**(gsampler2DRect *sampler*, vec2 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)
float **textureGradOffset**(sampler2DRectShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)
float **textureGradOffset**(sampler1DShadow *sampler*, vec3 *P*, float *dPdx*, float *dPdy*, int *offset*)
float **textureGradOffset**(sampler2DShadow *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)
gvec4 **textureGradOffset**(gsampler1DArray *sampler*, vec2 *P*, float *dPdx*, float *dPdy*, int *offset*)
gvec4 **textureGradOffset**(gsampler2DArray *sampler*, vec3 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)
float **textureGradOffset**(sampler1DArrayShadow *sampler*, vec3 *P*, float *dPdx*, float *dPdy*, int *offset*)
float **textureGradOffset**(sampler2DArrayShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)

Texture lookup both projectively as in **textureProj**, and with explicit gradient as in **textureGrad**.

gvec4 **textureProjGrad**(gsampler1D *sampler*, vec{2,4} *P*, float *dPdx*, float *dPdy*)
gvec4 **textureProjGrad**(gsampler2D *sampler*, vec{3,4} *P*, vec2 *dPdx*, vec2 *dPdy*)

(more ↓)

Texture lookup projectively, with gradient (continued)

gvec4 **textureProjGrad**(gsampler3D *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*)
gvec4 **textureProjGrad**(gsampler2DRect *sampler*, vec{3,4} *P*, vec2 *dPdx*, vec2 *dPdy*)
float **textureProjGrad**(sampler2DRectShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*)
float **textureProjGrad**(sampler1DShadow *sampler*, vec4 *P*, float *dPdx*, float *dPdy*)
float **textureProjGrad**(sampler2DShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*)

Texture lookup projectively and with explicit gradient as in **textureProjGrad**, as well as with offset as in **textureOffset.**

gvec4 **textureProjGradOffset**(gsampler1D *sampler*, vec{2,4} *P*, float *dPdx*, float *dPdy*, int *offset*)
gvec4 **textureProjGradOffset**(gsampler2D *sampler*, vec{3,4} *P*, vec2 *dPdx*, vec2 *dPdy*, vec2 *offset*)
gvec4 **textureProjGradOffset**(gsampler2DRect *sampler*, vec{3,4} *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)
float **textureProjGradOffset**(sampler2DRectShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*, ivec2 *offset*)
gvec4 **textureProjGradOffset**(gsampler3D *sampler*, vec4 *P*, vec3 *dPdx*, vec3 *dPdy*, vec3 *offset*)
float **textureProjGradOffset**(sampler1DShadow *sampler*, vec4 *P*, float *dPdx*, float *dPdy*, int *offset*)
float **textureProjGradOffset**(sampler2DShadow *sampler*, vec4 *P*, vec2 *dPdx*, vec2 *dPdy*, vec2 *offset*)

Texture Gather Instructions [8.9.3]

Texture gather operation.

gvec4 **textureGather**(gsampler2D *sampler*, vec2 *P* [, int *comp*])
gvec4 **textureGather**(gsampler2DArray *sampler*, vec3 *P* [, int *comp*])
gvec4 **textureGather**(gsamplerCube *sampler*, vec3 *P* [, int *comp*])
gvec4 **textureGather**(gsamplerCubeArray *sampler*, vec4 *P*[, int *comp*])
gvec4 **textureGather**(gsampler2DRect *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*)
vec4 **textureGather**(samplerCubeArrayShadow *sampler*, vec4 *P*, float *refZ*)
vec4 **textureGather**(sampler2DRectShadow *sampler*, vec2 *P*, float *refZ*)

Texture gather as in **textureGather** by offset as described in **textureOffset** except minimum and maximum offset values are given by {MIN, MAX}_PROGRAM_TEXTURE_GATHER_OFFSET.

gvec4 **textureGatherOffset**(gsampler2D *sampler*, vec2 *P*, ivec2 *offset* [, int *comp*])
gvec4 **textureGatherOffset**(gsampler2DArray *sampler*, vec3 *P*, ivec2 *offset* [, int *comp*])
gvec4 **textureGatherOffset**(gsampler2DRect *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*)
vec4 **textureGatherOffset**(sampler2DRectShadow *sampler*, vec2 *P*, float *refZ*, ivec2 *offset*)

Texture gather as in **textureGatherOffset** except that *offsets* is used to determine the location of the four texels to sample.

gvec4 **textureGatherOffsets**(gsampler2D *sampler*, vec2 *P*, ivec2 *offset*[4] [, int *comp*])
gvec4 **textureGatherOffsets**(gsampler2DArray *sampler*, vec3 *P*, ivec2 *offset*[4] [, int *comp*])
gvec4 **textureGatherOffsets**(gsampler2DRect *sampler*, vec3 *P*, ivec2 *offset*[4][, int *comp*])
vec4 **textureGatherOffsets**(sampler2DShadow *sampler*, vec2 *P*, float *refZ*, ivec2 *offset*[4])
vec4 **textureGatherOffsets**(sampler2DArrayShadow *sampler*, vec3 *P*, float *refZ*, ivec2 *offset*[4])
vec4 **textureGatherOffsets**(sampler2DRectShadow *sampler*, vec2 *P*, float *refZ*, ivec2 *offset*[4])

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