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 4.2 core profile and present only in the OpenGL 4.2 compatibility profile. Profile selection is made at context creation.
- **[n.n.n]** and **[Table n.n]** refer to sections and tables in the OpenGL 4.2 core specification.
- **[n.n.n]** and **[Table n.n]** refer to sections and tables in the OpenGL 4.2 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 4.20 specification.

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]

For all the functions in this section:
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 **DrawArraysOneInstance**(enum *mode*, int *first*, sizei *count*, int *instance*, uint *baseinstance*);

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

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

void **DrawArraysInstancedBaseInstance**(enum *mode*, int *first*, sizei *count*, sizei *primcount*, uint *baseinstance*);

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

void **MultiDrawArrays**(enum *mode*, const int **first*, const sizei **count*, 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 **DrawElementsInstancedBaseInstance**(enum *mode*, sizei *count*, enum *type*, const void **indices*, sizei *primcount*, uint *baseinstance*);

void **DrawElementsInstancedBaseVertex BaseInstance**(enum *mode*, sizei *count*, enum *type*, const void **indices*, sizei *primcount*, int *basevertex*, uint *baseinstance*);

void **DrawElementsOneInstance**(enum *mode*, sizei *count*, enum *type*, const void **indices*, int *instance*, uint *baseinstance*);

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*);

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}

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 is passed by a pointer.

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

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 Drawing Commands [2.8.3] on this card

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}**(T *coords*);

void **Normal3{bsifd}v**(const 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 **VertexAttribL{1234}d**(uint *index*, T *values*);

void **VertexAttribL{1234}dv**(uint *index*, const T *values*);

void **VertexAttribP{1234}ui**(uint *index*, enum *type*, boolean *normalized*, uint *value*)

void **VertexAttribP{1234}uiv**(uint *index*, enum *type*, boolean *normalized*, const uint **value*);
type: see VertexP{234}uiv

Buffer Objects [2.9-10]

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, ARRAY, TEXTURE}_BUFFER, COPY_{READ, WRITE}_BUFFER, DRAW_INDIRECT_BUFFER, ELEMENT_ARRAY_BUFFER, {TRANSFORM_FEEDBACK, ATOMIC_COUNTER}_BUFFER

void **BindBufferRange**(enum *target*, uint *index*, uint *buffer*, intptr *offset*, sizeiptr *size*);
target: ATOMIC_COUNTER_BUFFER, {TRANSFORM_FEEDBACK, UNIFORM}_BUFFER

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

Creating Buffer Object Data Stores [2.9.2]

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

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

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

(Buffer Objects Continue >)

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Buffer Objects (cont.)

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*);

Vertex Array Object Queries [6.1.10] [6.1.16]

boolean **IsVertexArray**(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

Rectangles, Matrices, Texture Coordinates

Rectangles [2.11]

Specify 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}**(Tθ, 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
Enable/Disable(*arg*);
arg: TEXTURE_GEN_{S, T, R, Q}

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_{READ, FRAGMENT, 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_{VEC*n*, MAT*n*, MAT*nxm*}, FLOAT, {UNSIGNED_}INT, {UNSIGNED_} 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, or UNIFORM_BLOCK_REFERENCED_BY_*x*_SHADER, where *x* may be one of VERTEX, FRAGMENT, GEOMETRY, TESS_CONTROL, or TESS_EVALUATION
void **GetActiveAtomicCounterBufferBindingsiv**(uint *program*, uint *bufferBindingIndex*, enum *pname*, int *params);
pname: ATOMIC_COUNTER_BUFFER_BINDING, ATOMIC_COUNTER_BUFFER_DATA_SIZE, ATOMIC_COUNTER_BUFFER_ACTIVE_ATOMIC_{COUNTERS, COUNTER_INDICES}, ATOMIC_COUNTER_BUFFER_REFERENCED_BY_{VERTEX, TESS_CONTROL, GEOMETRY, FRAGMENT}_SHADER, UNIFORM_BLOCK_REFERENCED_BY_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*nxn*}, FLOAT, FLOAT_{VEC*n*, MAT*n*, MAT*nxn*}, INT, INT_VEC*n*, UNSIGNED_INT{_VEC*n*}, BOOL, BOOL_VEC*n*, or any value in [Table 2.13] [Table 2.16]

(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*);
mode: *see Drawing Commands [2.8.3] on this card*
void **DrawTransformFeedbackInstanced**(enum *mode*, uint *id*, sizei *primcount*);
void **DrawTransformFeedbackStream**(enum *mode*, uint *id*, uint *stream*);
void **DrawTransformFeedbackStreamInstanced**(enum *mode*, uint *id*, uint *stream*, sizei *primcount*);

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]);

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Shaders and Programs (cont.)

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 [2.11.9] [2.14.9]

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*);

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

Varying Variables [2.11.12] [2.14.12]

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 [2.11.13] [2.14.13]

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

Shader Memory Access [2.11.14] [2.14.14]

void **MemoryBarrier**(bitfield *barriers*);
barriers: ALL_BARRIER_BITS or the OR of: {VERTEX_ATTRIB_ARRAY, ELEMENT_ARRAY, UNIFORM, TEXTURE_FETCH, BUFFER_UPDATE, SHADER_IMAGE_ACCESS, COMMAND, PIXEL_BUFFER, TEXTURE_UPDATE, FRAMEBUFFER, TRANSFORM_FEEDBACK, ATOMIC_COUNTER}_BARRIER_BIT

Tessellation Control Shaders [2.12.1-2] [2.15.1-2]

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

Fragment Shaders [3.10.2] [3.13.2]

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: CURRENT_VERTEX_ATTRIB or VERTEX_ATTRIB_ARRAY_*x* where *x* is one of BUFFER_BINDING, DIVISOR, ENABLED, INTEGER, NORMALIZED, SIZE, STRIDE, or TYPE

void **GetVertexAttribI{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{_BLOCKS}, ACTIVE_ATTRIBUTES_MAX_LENGTH, ACTIVE_UNIFORM_MAX_LENGTH, TRANSFORM_FEEDBACK_BUFFER_MODE, TRANSFORM_FEEDBACK_ VARYINGS, 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, SPACING, 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: The clamp bounds, if *pname* is POINT_SIZE_{MIN, MAX};
A pointer to coefficients *a*, *b*, and *c*, if *pname* is POINT_DISTANCE_ATTENUATION;
The fade threshold if *pname* is POINT_FADE_THRESHOLD_SIZE;
{LOWER|UPPER}_LEFT if *pname* is POINT_SPRITE_COORD_ORIGIN.

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, 6.1.6]

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), UNPACK_COMPRESSED_BLOCK_{WIDTH, HEIGHT, DEPTH, SIZE}

Pixel Transfer Modes [3.7.3, 6.1.3]

void **PixelTransfer{if}**(enum *param*, T *value*);
param: MAP_{COLOR, STENCIL}, *x*_{SCALE, BIAS}, INDEX_{SHIFT, OFFSET}, 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: COLOR_TABLE, 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*
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}

(Rasterization Continue >)

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Rasterization (continued)

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 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, FRONT_AND_BACK, BACK{_LEFT, _RIGHT}, 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 **StencilMask**(uint *mask*);

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

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

Clearing the Buffers [4.2.3]

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 [3.11]

Enable/Disable(COLOR_SUM)

Fog [3.12]

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, PERSPECTIVE_CORRECTION_HINT, POINT_SMOOTH_HINT, FOG_HINT, GENERATE_MIPMAP_HINT, TEXTURE_COMPRESSION_HINT, {LINE, POLYGON}_SMOOTH_HINT,
hint: FASTEST, NICEST, DONT_CARE

Texturing [3.9] [3.10]

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

Texture Objects [3.9.1] [3.10.1]

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 [3.9.2] [3.10.2]

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. [3.9.3] [3.10.3]

void **TexImage3D**(enum *target*, int *level*, int *internalformat*, sizei *width*, sizei *height*, sizei *depth*, int *border*, enum *format*, enum *type*, const void **data*);
target: TEXTURE_{3D, 2D_ARRAY, CUBE_MAP_ARRAY}, PROXY_TEXTURE_{3D, 2D_ARRAY, CUBE_MAP_ARRAY}
internalformat: ALPHA, DEPTH_COMPONENT, DEPTH_STENCIL, LUMINANCE_ALPHA, LUMINANCE, RED, INTENSITY, RG, RGB, RGBA; or a sized internal format from [Tables 3.12-3.13] [Tables 3.17-3.19]; COMPRESSED_{RED_RGTC1,RG_RGTC2}, COMPRESSED_SIGNED_{RED_RGTC1,RG_RGTC2}, or a generic comp. format in [Table 3.14] [Table 3.20]
format: COLOR_INDEX, DEPTH_COMPONENT, DEPTH_STENCIL, RED, GREEN, BLUE, ALPHA, RG, RGB, RGBA, BGR, BGRA, LUMINANCE, 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, 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: TEXTURE_{2D, RECTANGLE,CUBE_MAP}, PROXY_TEXTURE_{2D, RECTANGLE,CUBE_MAP}, TEXTURE_1D_ARRAY, PROXY_TEXTURE_1D_ARRAY, TEXTURE_CUBE_MAP_POSITIVE_{X, Y, Z}, TEXTURE_CUBE_MAP_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. [3.9.4] [3.10.4]

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*);
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 [3.9.5] [3.10.5]

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**

(Texturing Continue >)

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Texturing (continued)

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 [3.9.6] [3.10.6]

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 [3.9.7] [3.10.7]

void **TexBuffer**(enum *target*, enum *internalformat*, uint *buffer*);
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 [3.9.8] [3.10.8]

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_COMPARE_{MODE, FUNC}, TEXTURE_{BASE, MAX}_LEVEL [Table 3.16] [Table 3.22]

Cube Map Texture Select [3.9.10] [3.10.10]

Enable/Disable(TEXTURE_CUBE_MAP_SEAMLESS)

Texture Minification [3.9.11] [3.10.11]

void **GenerateMipmap**(enum *target*);
target: TEXTURE_{1D, 2D, 3D}, TEXTURE_{1D, 2D}_ARRAY, TEXTURE_CUBE_MAP{_ARRAY}

Immutable-Format Texture Images [3.9.16] [3.10.16]

void **TexStorage1D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*);
target: TEXTURE_1D, PROXY_TEXTURE_1D
internalformat: any of the sized internal color, luminance, intensity, depth, and stencil formats in [Tables 3.12-13] [Table 3.17-19]

void **TexStorage2D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*, sizei *height*);
target: TEXTURE_2D, PROXY_TEXTURE_2D, TEXTURE_{RECTANGLE, CUBE_MAP, 1D_ARRAY}, PROXY_TEXTURE_{RECTANGLE, CUBE_MAP, 1D_ARRAY}
internalformat: see *TexStorage1D*

void **TexStorage3D**(enum *target*, sizei *levels*, enum *internalformat*, sizei *width*, sizei *height*, sizei *depth*);
target: TEXTURE_3D, PROXY_TEXTURE_3D, TEXTURE_{2D, CUBE_MAP}[_ARRAY], PROXY_TEXTURE_{CUBE_MAP, 2D}[_ARRAY]
internalformat: see *TexStorage1D*

Texture Environments & Functions [3.10.17]

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 [3.10.21]

Enable/Disable(*param*)
param: TEXTURE_{1D, 2D, 3D}, TEXTURE_CUBE_MAP

Texture Image Loads/Stores [3.9.20][3.10.22]

void **BindImageTexture**(uint *index*, uint *texture*, int *level*, boolean *layered*, int *layer*, enum *access*, enum *format*);
access: READ_ONLY, WRITE_ONLY, READ_WRITE
format: RGBA{32,16}F, RG{32,16}F, R11F_G11F_B10F, R{32,16}F, RGBA{32,16,8}UI, RGB10_A2UI, RG{32,16,8}UI, R{32,16,8}UI, RGBA{32,16,8}I, RG{32,16,8}I, R{32,16,8}I, RGBA{16,8}, RGB10_A2, RG{16,8}, R{16,8}, RGBA{16,8}_SNORM, RG{16,8}_SNORM, R{16,8}_SNORM [Table 3.21] [Table 3.33]

Enumerated Queries [6.1.15] [6.1.21]

void **GetInternalformativ**(enum *target*, enum *internalformat*, enum *pname*, sizei *bufSize*, int **params*);
internalformat: must be color-renderable, depth-renderable, or stencil-renderable
target: RENDERBUFFER, TEXTURE_2D_MULTISAMPLE, TEXTURE_2D_MULTISAMPLE_ARRAY
pname: NUM_SAMPLE_COUNTS, SAMPLES

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, IMAGE_FORMAT_COMPATIBILITY_TYPE, TEXTURE_IMMUTABLE_FORMAT, 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}, {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)

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, GREATER, GEQUAL, 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, {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

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*);

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*);
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

(Framebuffer Objects Continue >)

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Framebuffer Objects (cont'd)

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*);
(parameters ↴)
textarget: TEXTURE_{2D, RECTANGLE}, TEXTURE_2D_MULTISAMPLE, 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
attachment: FRONT_{LEFT, RIGHT}, BACK_{LEFT,RIGHT}, COLOR_ATTACHMENT*i*, AUX*i*, DEPTH, STENCIL, {DEPTH, STENCIL}_ATTACHMENT, DEPTH_STENCIL_ATTACHMENT
(more parameters ↴)
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)

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]
(more parameters ↴)
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]

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.*

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*);

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 and 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);

OpenGL Shading Language 4.20 Reference Card

The OpenGL® Shading Language is used to create shaders for each of the programmable processors contained in the OpenGL processing pipeline. The OpenGL Shading Language is actually several closely related languages. Currently, these processors are the vertex, tessellation control, tessellation evaluation, geometry, and fragment processors.

[n.n.n] and **[Table n.n]** refer to sections and tables in the OpenGL Shading Language 4.20 specification at www.opengl.org/registry

Content shown in blue is removed from the OpenGL 4.2 core profile and present only in the OpenGL 4.2 compatibility profile.

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 420 #version 420 *profile*	"#version 420" is required in shaders using version 4.20 of the language. Use *profile* to indicate core or compatibility. 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	#if
#extension	#version	#ifdef	#ifndef
#error	#include	#line	#endif
#pragma	#undef	#else	

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.: 420

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 Opaque Types

sampler[1,2,3]D	1D, 2D, or 3D texture
image[1,2,3]D	1D, 2D, or 3D image
samplerCube	cube mapped texture
imageCube	cube mapped image
sampler2DRect	rectangular texture
image2DRect	rectangular image
sampler[1,2]DShadow	[1,2]D depth tex./compare
sampler2DRectShadow	rectangular tex./compare
sampler[1,2]DArray	1D or 2D array texture
image[1,2]DArray	1D or 2D array image
sampler[1,2]DArrayShadow	1D or 2D array depth texture/comparison
samplerBuffer	buffer texture
imageBuffer	buffer image
sampler2DMS	2D multi-sample texture
image2DMS	2D multi-sample image
sampler2DMSArray	2D multi-sample array tex.
image2DMSArray	2D multi-sample array img.
samplerCubeArray	cube map array texture
imageCubeArray	cube map array image
samplerCubeArrayShadow	cube map array depth texture with comparison

Signed Integer Opaque Types

isampler[1,2,3]D	integer 1D, 2D, or 3D texture
iimage[1,2,3]D	integer 1D, 2D, or 3D image
isamplerCube	integer cube mapped texture
iimageCube	integer cube mapped image

Continue ⤴

Signed Integer Opaque Types (cont'd)

isampler2DRect	int. 2D rectangular texture
iimage2DRect	int. 2D rectangular image
isampler[1,2]DArray	integer 1D, 2D array texture
iimage[1,2]DArray	integer 1D, 2D array image
isamplerBuffer	integer buffer texture
iimageBuffer	integer buffer image
isampler2DMS	int. 2D multi-sample texture
iimage2DMS	int. 2D multi-sample image
isampler2DMSArray	int. 2D multi-sample array tex.
iimage2DMSArray	int. 2D multi-sample array image
isamplerCubeArray	int. cube map array texture
iimageCubeArray	int. cube map array image

Unsigned Integer Opaque Types

atomic_uint	uint atomic counter
usampler[1,2,3]D	uint 1D, 2D, or 3D texture
uimage[1,2,3]D	uint 1D, 2D, or 3D image
usamplerCube	uint cube mapped texture
uimageCube	uint cube mapped image
usampler2DRect	uint rectangular texture
uimage2DRect	uint rectangular image
usampler[1,2]DArray	1D or 2D array texture
uimage[1,2]DArray	1D or 2D array image
usamplerBuffer	uint buffer texture
uimageBuffer	uint buffer image
usampler2DMS	uint 2D multi-sample texture
uimage2DMS	uint 2D multi-sample image

Continue ⤴

Unsigned Integer Opaque Types (cont'd)

usampler2DMSArray	uint 2D multi-sample array tex.
uimage2DMSArray	uint 2D multi-sample array image
usamplerCubeArray	uint cube map array texture
uimageCubeArray	uint cube map array image

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, uvec2|3|4	->	vec2|3|4
vec2|3|4	->	dvec2|3|4
ivec2|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

Operators & Expressions [5.1]

The following operators are numbered in order of precedence. Relational and equality operators evaluate to Boolean. Also see lessThan(), equal(), etc.

1.	**( )**	parenthetical grouping
2.	**[ ]** **( )** **.** **++ --**	array subscript function call, constructor, structure field, 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.
16.	**= += -=** ***= /=** **%= <<= >>=** **&= ^= |=**	assignment arithmetic assignments
17.	**,**	sequence

Vector & Scalar Components [5.5]

In addition to array numeric subscript syntax, names of vector and scalar components are denoted by a single letter. Components can be swizzled and replicated. Scalars have only an *x*, *r*, or *s* component.

{x, y, z, w}	Points or normals
{r, g, b, a}	Colors
{s, t, p, q}	Texture coordinates

Qualifiers

Storage Qualifiers [4.3]

Declarations may have one storage qualifier.

none	(default) local read/write memory, or input parameter
const	global compile-time constant, or read-only function parameter, or read-only local variable
in	linkage into shader from previous stage
out	linkage out of a shader to next stage
attribute	same as **in** for vertex shader
uniform	linkage between a shader, OpenGL, and the application
varying	same as **in** for vertex shader, same as **out** for fragment shader

Auxiliary Storage Qualifiers

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

centroid	centroid-based interpolation
sampler	per-sample interpolation
patch	per-tessellation-patch attributes

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 [4.4.1]

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

For "in" only (not with variable declarations):
early_fragment_tests

Output Layout Qualifiers [4.4.2]

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

Fragment shader outputs:
depth_any, depth_greater, depth_less, depth_unchanged

For fragment shaders:
index = *integer-constant*

Uniform-Block Layout Qualifiers [4.4.3]

Layout qualifier identifiers for uniform blocks:
shared, packed, std140, {row, column}_major
binding = *integer-constant*

Opaque Uniform Layout Qualifiers [4.4.4]

Used to bind opaque uniform variables to specific buffers or units.
binding = *integer-constant*

Atomic Counter Layout Qualifiers [4.4.4.1]

binding = *integer-constant*
offset = *integer-constant*

Format Layout Qualifiers [4.4.4.2]

One qualifier may be used with variables declared as "image" to specify the image format.

For tessellation control shaders:
binding = *integer-constant*,
rgba{32,16}f, rg{32,16}f, r{32,16}f, r11f_g11f_b10f, rgb10_a2{ui}, rgba{16,8}, rg{16,8}, r{16,8}, rgba{32,16,8}i, rg{32,16,8}i,r{32,16,8}i, rgba{32,16,8}ui, rg{32,16,8}ui, r{32,16,8}ui, rgba{16,8}_snorm, rg{16,8}_snorm, r{16,8}_snorm,

Interpolation Qualifiers [4.5]

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_BackColor gl_FrontSecondaryColor gl_BackSecondaryColor	gl_Color gl_SecondaryColor

Parameter Qualifiers [4.6]

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
const	for function parameters that cannot be written to
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 [4.7]

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

highp, mediump, lowp

Invariant Qualifiers Examples [4.8.1]

#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 [4.9]

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;

(Qualifiers Continue >)

Qualifiers (continued)

Memory Qualifiers [4.10]

Variables qualified as "image" can have one or more memory qualifiers.

coherent	reads and writes are coherent with other shader invocations
volatile	underlying values may be changed by other sources
restrict	won't be accessed by other code
readonly	read only
writeonly	write only

Order of Qualification [4.11]

When multiple qualifiers are present in a declaration they may appear in any order, but must all appear before the type. The layout qualifier is the only qualifier that can appear more than once. Further, a declaration can have at most one storage qualifier, at most one auxiliary storage qualifier, and at most one interpolation qualifier. Multiple memory qualifiers can be used. Any violation of these rules will cause a compile-time error.

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];

  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];
```

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_MaxVaryingFloats = 60;
const int gl_MaxVertexAttribs = 16;
const int gl_MaxVertexUniformComponents = 1024;
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_MaxImageUnits = 8;
const int
  gl_MaxCombinedImageUnitsAndFragmentOutputs = 8;
const int gl_MaxImageSamples = 0;
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;
```

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  int   gl_SampleMask[];
  in gl_PerFragment {
      in  float gl_FogFragCoord;
      in  vec4  gl_TexCoord[];
      in  vec4  gl_Color;
      in  vec4  gl_SecondaryColor;
  };

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

```
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;
const int gl_MaxVertexAtomicCounters = 0;
const int gl_MaxTessControlAtomicCounters = 0;
const int gl_MaxTessEvaluationAtomicCounters = 0;
const int gl_MaxGeometryAtomicCounters = 0;
const int gl_MaxFragmentAtomicCounters = 8;
const int gl_MaxCombinedAtomicCounters = 8;
const int gl_MaxAtomicCounterBindings = 1;
const int gl_MinProgramTexelOffset = -7;
const int gl_MaxProgramTexelOffset = 8;
```

Operations and Constructors

Vector & Matrix [5.4.2]

.**length**() for matrices returns number of columns
.**length**() for vectors returns number of components

```
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 Example [5.4.3]

.**length**() for structures returns number of members

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

Array Example [5.4.4]

.**length**() for arrays returns number of elements

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

Matrix 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 or **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]

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

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;
```

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

(Built-In Common Functions Continue >)

Built-In Functions (continued)

Common Functions (continued)

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
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 **packSnorm2x16**(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*) vec2 **unpackSnorm2x16**(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*.
uint **packHalf2x16**(vec2 *v*)	Returns a uint by converting the components of a two-component floating-point vector
vec2 **unpackHalf2x16**(uint *v*)	Returns a two-component floating-point vector

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
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*

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.

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 uint*x* 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.
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]

Available to vertex, geometry, and fragment shaders. See tables on next page.

Atomic-Counter Functions [8.10]

The value returned by these functions is the value of an atomic counter.

uint **atomicCounterIncrement**(atomic_uint *c*)	Atomically returns the value of counter for *c*, then increments.
uint **atomicCounterDecrement**(atomic_uint *c*)	Atomically decrements counter for *c*, then returns value of counter for *c*.
uint **atomicCounter**(atomic_uint *c*)	Atomically returns the counter for *c*.

Image Functions [8.11]

In these image functions, IMAGE_PARAMS may be one of the following:

gimage1D image, int P
gimage2D image, ivec2 P
gimage3D image, ivec3 P
gimage2DRect image, ivec2 P
gimageCube image, ivec3 P
gimageBuffer image, int P
gimage1DArray image, ivec2 P
gimage2DArray image, ivec3 P
gimageCubeArray image, ivec3 P
gimage2DMS image, ivec2 P, int sample
gimage2DMSArray image, ivec3 P, int sample

gvec4 **imageLoad**(readonly IMAGE_PARAMS)	Loads the texel at the coordinate *P* from the image unit *image*.
void **imageStore**(writeonly IMAGE_PARAMS, gvec4 *data*)	Stores *data* into the texel at the coordinate *P* from the image specified by *image*.
uint **imageAtomicAdd**(IMAGE_PARAMS, uint *data*) int **imageAtomicAdd**(IMAGE_PARAMS, int *data*)	Adds the value of *data* to the contents of the selected texel.
uint **imageAtomicMin**(IMAGE_PARAMS, uint *data*) int **imageAtomicMin**(IMAGE_PARAMS, int *data*)	Takes the minimum of the value of *data* and the contents of the selected texel.

Continue ⤴

Image Functions (continued)

uint **imageAtomicMax**(IMAGE_PARAMS, uint *data*) int **imageAtomicMax**(IMAGE_PARAMS, int *data*)	Takes the maximum of the value *data* and the contents of the selected texel.
uint **imageAtomicAnd**(IMAGE_PARAMS, uint *data*) int **imageAtomicAnd**(IMAGE_PARAMS, int *data*)	Performs a bit-wise and of the value of *data* and the contents of the selected texel.
uint **imageAtomicOr**(IMAGE_PARAMS, uint *data*) int **imageAtomicOr**(IMAGE_PARAMS, int *data*)	Performs a bit-wise or of the value of *data* and the contents of the selected texel.
uint **imageAtomicXor**(IMAGE_PARAMS, uint *data*) int **imageAtomicXor**(IMAGE_PARAMS, int *data*)	Performs a bit-wise exclusive or of the value of *data* and the contents of the selected texel.
uint **imageAtomicExchange**(IMAGE_PARAMS, uint *data*) int **imageAtomicExchange**(IMAGE_PARAMS, int *data*)	Copies the value of *data*.
uint **imageAtomicCompSwap**(IMAGE_PARAMS, uint *compare*, uint *data*) int **imageAtomicCompSwap**(IMAGE_PARAMS, int *compare*, int *data*)	Compares the value of *compare* and contents of selected texel. If equal, the new value is given by *data*; otherwise, it is taken from the original value loaded from texel.

Fragment Processing Functions [8.12]

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

Derivative fragment-processing 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 fragment-processing 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 [8.13]

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 [8.14]

Only available in geometry shaders.

void **EmitStreamVertex**(int *stream*)	Emits values of output variables to 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.

Other Shader Functions [8.15-16]

void **barrier**()	Shader Invocation: Synchronizes across shader invocations.
void **memoryBarrier**()	Shader Memory Control: Control the ordering of memory transactions issued by a single shader invocation.

Texture Functions [8.9]

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

Texture Query Functions [8.9.1]

textureSize functions return dimensions of *lod* (if present) for the texture bound to sampler. Components in return value are filled in with the width, height, depth of the texture. For array forms, the last component of the return value is the number of layers in the texture array.

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*)
ivec3 **textureSize**(gsampler2DMSArray *sampler*)

textureQueryLod functions return the mipmap array(s) that would be accessed in the *x* component of the return value. Returns the computed level of detail relative to the base level in the *y* component of the return value.

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*. For shadow forms, when *compare* is present, it is used as D_{ref} and the array layer comes from *P*.w. For non-shadow forms, the array layer comes from the last component of *P*.

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*)
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*, ivec2 *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*, ivec3 *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]

These functions take components of a floating-point vector operand as a texture coordinate, determine a set of four texels to sample from the base level of detail of the specified texture image, and return one component from each texel in a four-component result vector.

gvec4 **textureGather**(gsampler2D *sampler*, vec2 *P* [, int *comp*])
gvec4 **textureGather**(gsampler2DArray *sampler*, vec3 *P* [, int *comp*])
gvec4 **textureGather**(gsamplerCube *sampler*, vec3 *P* [, int *comp*])
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 Functions Continue >)

Texture Functions (continued)

Texture Gather Instructions (continued)

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 *offsets* determines 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])

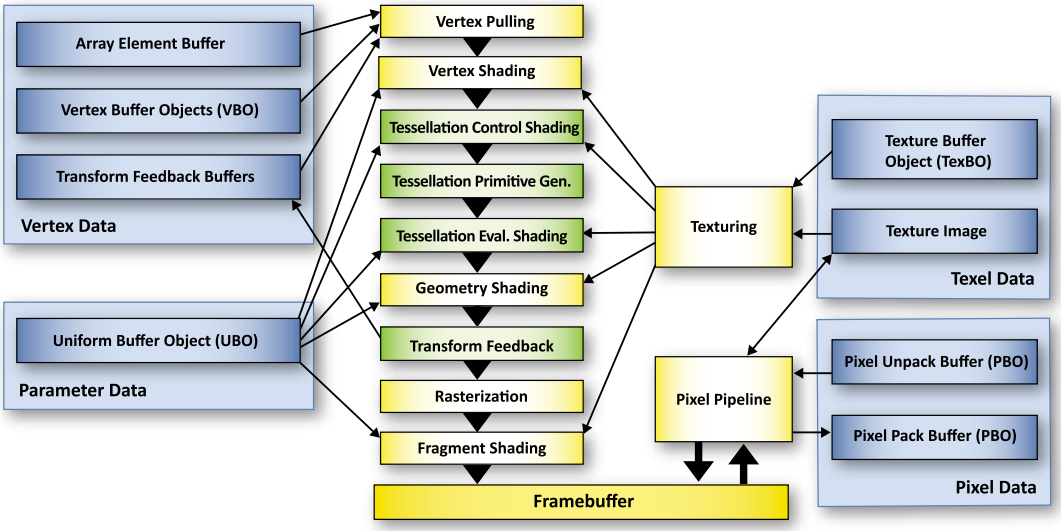
OpenGL Pipeline

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

The heavy black arrows in this illustration show the OpenGL pipeline. In order to fully take advantage of modern OpenGL, pay close attention to how to most efficiently use the new buffer types.

Blue blocks indicate various buffers that feed or get fed by the OpenGL pipeline.

Green blocks indicate features new or significantly changed with OpenGL 4.x.



Vertex & Tessellation Details

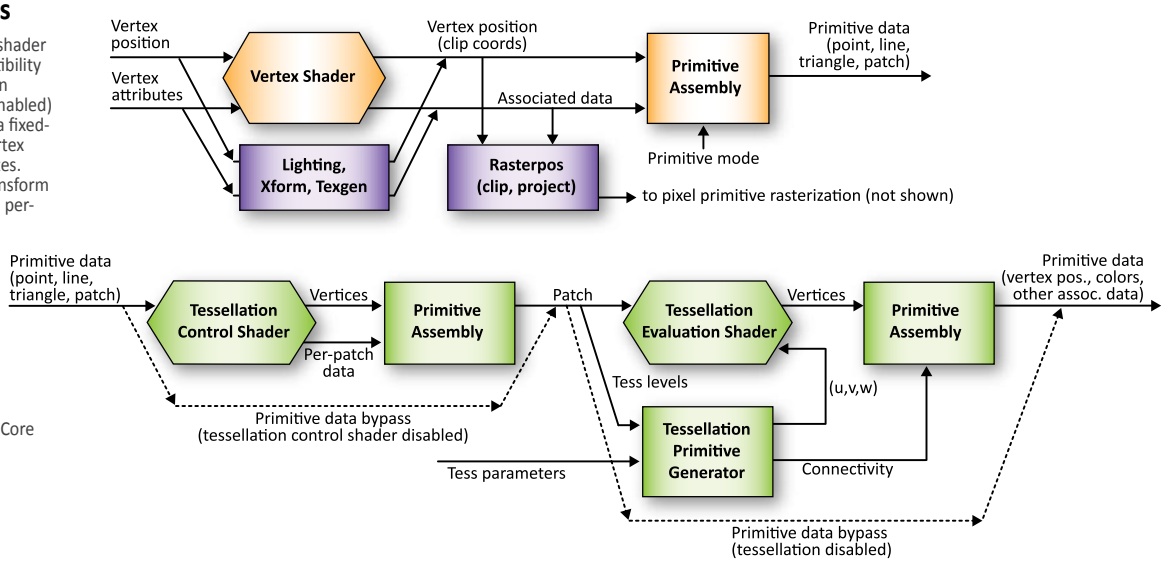
Each vertex is processed either by a vertex shader or fixed-function vertex processing (compatibility only) to generate a transformed vertex, then assembled into primitives. Tessellation (if enabled) operates on patch primitives, consisting of a fixed-size collection of vertices, each with per-vertex attributes and associated per-patch attributes. Tessellation control shaders (if enabled) transform an input patch and compute per-vertex and per-patch attributes for a new output patch.

A fixed-function primitive generator subdivides the patch according to tessellation levels computed in the tessellation control shaders or specified as fixed values in the API (TCS disabled). The tessellation evaluation shader computes the position and attributes of each vertex produced by the tessellator.

Orange blocks indicate features of the Core specification.

Purple blocks indicate features of the Compatibility specification.

Green blocks indicate features new or significantly changed with OpenGL 4.x.



Geometry & Follow-on Details

Geometry shaders (if enabled) consume individual primitives built in previous primitive assembly stages. For each input primitive, the geometry shader can output zero or more vertices, with each vertex directed at a specific vertex stream. The vertices emitted to each stream are assembled into primitives according to the geometry shader's output primitive type.

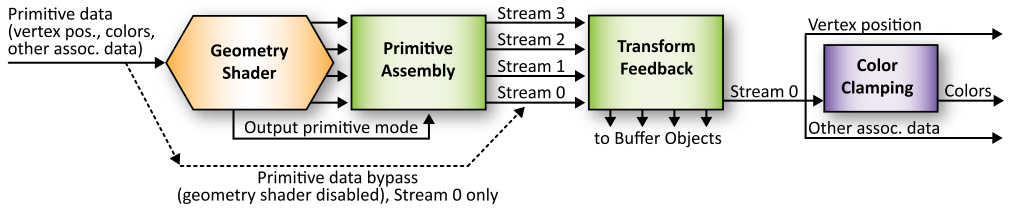
Transform feedback (if active) writes selected vertex attributes of the primitives of all vertex streams into buffer objects attached to one or more binding points.

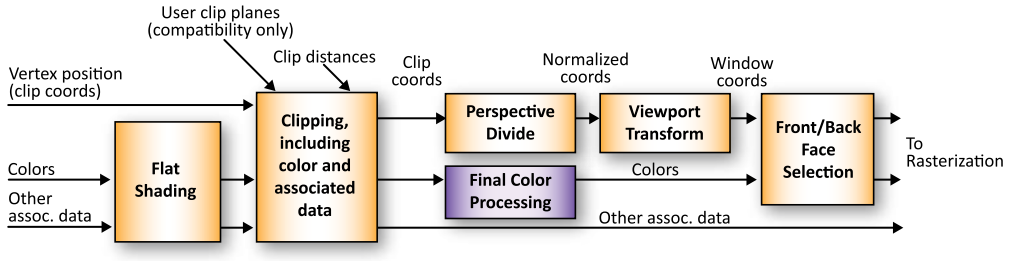
Primitives on vertex stream zero are then processed by fixed-function stages, where they are clipped and prepared for rasterization.

Orange blocks indicate features of the Core specification.

Purple blocks indicate features of the Compatibility specification.

Green blocks indicate features new or significantly changed with OpenGL 4.x.





OpenGL Reference Card Index

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

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