

Shader

GLSL Syntax

OpenGL Reference Card Page 6ff

| Page 6 | | OpenGL Shading Language 4.30 Reference Card | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| <p>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, fragment, and compute shaders.</p> <p>[n.n.n] and [Table n.n] refer to sections and tables in the OpenGL Shading Language 4.30 specification at www.khronos.org/registry.</p> | | <h3>Preprocessor [3.3]</h3> <h4>Preprocessor Directives</h4> <table> <tr> <td>#</td><td>Define</td><td>undef</td><td>if</td><td>ifdef</td><td>ifndef</td></tr> <tr> <td>#extension</td><td>#version</td><td>#ifdef</td><td>#ifndef</td><td>#undef</td><td>#pragma</td></tr> <tr> <td>#error</td><td>#include</td><td>else</td><td>endif</td><td></td><td></td></tr> </table> <h4>Preprocessor Operators</h4> <table> <tr> <td>#version 430</td><td>Required when using version 4.30.</td></tr> <tr> <td>#version 430 profile</td><td>profile is core, compatibility, or es</td></tr> <tr> <td>#extension</td><td>extension_name : behavior</td></tr> <tr> <td>extension_name : behavior</td><td>behavior: require, enable, warn, disable</td></tr> <tr> <td>extension_name : all : behavior</td><td>extension_name: extension supported by compiler, or "all"</td></tr> </table> <h4>Predefined Macros</h4> <table> <tr> <td>__LINE__</td><td>Decimal integer constants. __FILE__ says which source string is being processed.</td></tr> <tr> <td>__VERSION__</td><td>Decimal integer, e.g.: 430</td></tr> <tr> <td>GL_core_profile</td><td>Defined as 1.</td></tr> <tr> <td>GL_es_profile</td><td>1 if the implementation supports the es profile</td></tr> <tr> <td>GL_compatibility_profile</td><td>Defined as 1 if the implementation supports the compatibility profile.</td></tr> </table> | | # | Define | undef | if | ifdef | ifndef | #extension | #version | #ifdef | #ifndef | #undef | #pragma | #error | #include | else | endif | | | #version 430 | Required when using version 4.30. | #version 430 profile | profile is core, compatibility, or es | #extension | extension_name : behavior | extension_name : behavior | behavior: require, enable, warn, disable | extension_name : all : behavior | extension_name: extension supported by compiler, or "all" | __LINE__ | Decimal integer constants. __FILE__ says which source string is being processed. | __VERSION__ | Decimal integer, e.g.: 430 | GL_core_profile | Defined as 1. | GL_es_profile | 1 if the implementation supports the es profile | GL_compatibility_profile | Defined as 1 if the implementation supports the compatibility profile. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| # | Define | undef | if | ifdef | ifndef | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| #extension | #version | #ifdef | #ifndef | #undef | #pragma | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| #error | #include | else | endif | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| #version 430 | Required when using version 4.30. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| #version 430 profile | profile is core, compatibility, or es | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| #extension | extension_name : behavior | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| extension_name : behavior | behavior: require, enable, warn, disable | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| extension_name : all : behavior | extension_name: extension supported by compiler, or "all" | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| __LINE__ | Decimal integer constants. __FILE__ says which source string is being processed. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| __VERSION__ | Decimal integer, e.g.: 430 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GL_core_profile | Defined as 1. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GL_es_profile | 1 if the implementation supports the es profile | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| GL_compatibility_profile | Defined as 1 if the implementation supports the compatibility profile. | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <h3>Operators and Expressions [5.1]</h3> <p>The following operators are numbered in order of precedence. Relational and equality operators evaluate to Boolean. Also see lessThan(), equal(), etc.</p> <table> <tr> <td>1.</td><td>()</td><td>parenthetical grouping</td></tr> <tr> <td>2.</td><td>[]</td><td>array subscript</td></tr> <tr> <td>3.</td><td>{ }</td><td>function call, constructor, structure field, selector, switch</td></tr> <tr> <td>4.</td><td>++ --</td><td>postfix increment and decrement</td></tr> </table> | | 1. | () | parenthetical grouping | 2. | [] | array subscript | 3. | { } | function call, constructor, structure field, selector, switch | 4. | ++ -- | postfix increment and decrement | <table> <tr> <td>5.</td><td>++ --</td><td>prefix increment and decrement</td></tr> <tr> <td>6.</td><td>* / %</td><td>multiplicative</td></tr> <tr> <td>7.</td><td>+= -=</td><td>additive</td></tr> <tr> <td>8.</td><td><< >></td><td>bit-wise shift</td></tr> <tr> <td>9.</td><td>< > <= >=</td><td>relational</td></tr> <tr> <td>10.</td><td>== !=</td><td>equality</td></tr> <tr> <td>11.</td><td>&</td><td>bit-wise and</td></tr> <tr> <td>12.</td><td>*</td><td>bit-wise exclusive or</td></tr> <tr> <td>13.</td><td> </td><td>bit-wise inclusive or</td></tr> <tr> <td>14.</td><td>&&</td><td>logical and</td></tr> <tr> <td>15.</td><td>^^</td><td>logical exclusive or</td></tr> <tr> <td>16.</td><td> </td><td>logical inclusive or</td></tr> <tr> <td>17.</td><td>?:</td><td>selects an entire operand</td></tr> <tr> <td>18.</td><td>= += -= *= /= %+= %-=</td><td>assignment</td></tr> <tr> <td>19.</td><td>+= -= *= /= %+= %-=</td><td>arithmetic assignments</td></tr> <tr> <td>20.</td><td>?:</td><td>assignment</td></tr> <tr> <td>21.</td><td>?:</td><td>assignment</td></tr> </table> <h3>Vector & Scalar Components [5.5]</h3> <p>In addition to array numeric subscript syntax, names of vector and scalar components are denoted by a single letter. Components can be switched and replicated. Scalars have only an s, c, or a component.</p> <table> <tr> <td>(x, y, z, w)</td><td>Points or normals</td></tr> <tr> <td>(r, g, b, a)</td><td>Colors</td></tr> <tr> <td>(s, t, p, q)</td><td>Texture coordinates</td></tr> </table> | | 5. | ++ -- | prefix increment and decrement | 6. | * / % | multiplicative | 7. | += -= | additive | 8. | << >> | bit-wise shift | 9. | < > <= >= | relational | 10. | == != | equality | 11. | & | bit-wise and | 12. | * | bit-wise exclusive or | 13. | | bit-wise inclusive or | 14. | && | logical and | 15. | ^^ | logical exclusive or | 16. | | logical inclusive or | 17. | ?: | selects an entire operand | 18. | = += -= *= /= %+= %-= | assignment | 19. | += -= *= /= %+= %-= | arithmetic assignments | 20. | ?: | assignment | 21. | ?: | assignment | (x, y, z, w) | Points or normals | (r, g, b, a) | Colors | (s, t, p, q) | Texture coordinates | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1. | () | parenthetical grouping | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. | [] | array subscript | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. | { } | function call, constructor, structure field, selector, switch | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4. | ++ -- | postfix increment and decrement | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5. | ++ -- | prefix increment and decrement | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. | * / % | multiplicative | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7. | += -= | additive | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8. | << >> | bit-wise shift | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9. | < > <= >= | relational | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10. | == != | equality | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11. | & | bit-wise and | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12. | * | bit-wise exclusive or | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13. | | bit-wise inclusive or | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14. | && | logical and | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15. | ^^ | logical exclusive or | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16. | | logical inclusive or | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17. | ?: | selects an entire operand | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18. | = += -= *= /= %+= %-= | assignment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19. | += -= *= /= %+= %-= | arithmetic assignments | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20. | ?: | assignment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21. | ?: | assignment | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (x, y, z, w) | Points or normals | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (r, g, b, a) | Colors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (s, t, p, q) | Texture coordinates | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <h3>Types [4.1]</h3> <h4>Transparent Types</h4> <table> <tr> <td>void</td><td>no function return value</td></tr> <tr> <td>bool</td><td>Boolean</td></tr> <tr> <td>int, uint</td><td>signed/unsigned integers</td></tr> <tr> <td>float</td><td>single-precision floating-point scalar</td></tr> <tr> <td>double</td><td>double-precision floating-point scalar</td></tr> <tr> <td>vec2, vec3, vec4</td><td>floating-point vector</td></tr> <tr> <td>dvec2, dvec3, dvec4</td><td>double-precision floating-point vectors</td></tr> <tr> <td>bvec2, bvec3, bvec4</td><td>Boolean vectors</td></tr> <tr> <td>ivec2, ivec3, ivec4</td><td>signed and unsigned integer vectors</td></tr> <tr> <td>uvec2, uvec3, uvec4</td><td>signed and unsigned integer vectors</td></tr> <tr> <td>mat2, mat3, mat4</td><td>2x2, 3x3, 4x4 float matrix</td></tr> <tr> <td>mat2x2, mat2x3, mat2x4</td><td>2 column float matrix of 2, 3, or 4 rows</td></tr> </table> | | void | no function return value | bool | Boolean | int, uint | signed/unsigned integers | float | single-precision floating-point scalar | double | double-precision floating-point scalar | vec2, vec3, vec4 | floating-point vector | dvec2, dvec3, dvec4 | double-precision floating-point vectors | bvec2, bvec3, bvec4 | Boolean vectors | ivec2, ivec3, ivec4 | signed and unsigned integer vectors | 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 | <h4>Floating-Point Opaque Types</h4> <table> <tr> <td>sampler1D, sampler2D, sampler3D</td><td>1D, 2D, or 3D texture</td></tr> <tr> <td>image1D, image2D, image3D</td><td>image1D, image2D, image3D</td></tr> <tr> <td>samplerCube</td><td>cube mapped texture</td></tr> <tr> <td>imageCube</td><td>imageCube</td></tr> <tr> <td>sampler2DRect</td><td>rectangular texture</td></tr> <tr> <td>image2DRect</td><td>image2DRect</td></tr> <tr> <td>sampler1DArray, sampler2DArray, sampler3DArray</td><td>1D or 2D array texture</td></tr> <tr> <td>image1DArray, image2DArray, image3DArray</td><td>image1DArray, image2DArray, image3DArray</td></tr> <tr> <td>samplerBuffer</td><td>buffer texture</td></tr> <tr> <td>imageBuffer</td><td>imageBuffer</td></tr> <tr> <td>sampler2DMS, sampler3DMS</td><td>2D multi-sample texture</td></tr> <tr> <td>image2DMS, image3DMS</td><td>image2DMS, image3DMS</td></tr> <tr> <td>sampler2DMSArray, sampler3DMSArray</td><td>2D multi-sample array texture</td></tr> <tr> <td>image2DMSArray, image3DMSArray</td><td>image2DMSArray, image3DMSArray</td></tr> <tr> <td>samplerCubeArray</td><td>cube map array texture</td></tr> <tr> <td>imageCubeArray</td><td>imageCubeArray</td></tr> <tr> <td>sampler2DShadow</td><td>1D or 2D depth texture with comparison</td></tr> <tr> <td>image2DShadow</td><td>image2DShadow</td></tr> <tr> <td>sampler3DShadow</td><td>3D depth texture with comparison</td></tr> <tr> <td>image3DShadow</td><td>image3DShadow</td></tr> </table> | | sampler1D, sampler2D, sampler3D | 1D, 2D, or 3D texture | image1D, image2D, image3D | image1D, image2D, image3D | samplerCube | cube mapped texture | imageCube | imageCube | sampler2DRect | rectangular texture | image2DRect | image2DRect | sampler1DArray, sampler2DArray, sampler3DArray | 1D or 2D array texture | image1DArray, image2DArray, image3DArray | image1DArray, image2DArray, image3DArray | samplerBuffer | buffer texture | imageBuffer | imageBuffer | sampler2DMS, sampler3DMS | 2D multi-sample texture | image2DMS, image3DMS | image2DMS, image3DMS | sampler2DMSArray, sampler3DMSArray | 2D multi-sample array texture | image2DMSArray, image3DMSArray | image2DMSArray, image3DMSArray | samplerCubeArray | cube map array texture | imageCubeArray | imageCubeArray | sampler2DShadow | 1D or 2D depth texture with comparison | image2DShadow | image2DShadow | sampler3DShadow | 3D depth texture with comparison | image3DShadow | image3DShadow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| void | no function return value | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| bool | Boolean | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| int, uint | signed/unsigned integers | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| float | single-precision floating-point scalar | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| double | double-precision floating-point scalar | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec2, vec3, vec4 | floating-point vector | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| dvec2, dvec3, dvec4 | double-precision floating-point vectors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| bvec2, bvec3, bvec4 | Boolean vectors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| ivec2, ivec3, ivec4 | signed and unsigned integer vectors | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 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 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler1D, sampler2D, sampler3D | 1D, 2D, or 3D texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image1D, image2D, image3D | image1D, image2D, image3D | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| samplerCube | cube mapped texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageCube | imageCube | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler2DRect | rectangular texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DRect | image2DRect | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler1DArray, sampler2DArray, sampler3DArray | 1D or 2D array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image1DArray, image2DArray, image3DArray | image1DArray, image2DArray, image3DArray | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| samplerBuffer | buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | imageBuffer | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler2DMS, sampler3DMS | 2D multi-sample texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMS, image3DMS | image2DMS, image3DMS | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler2DMSArray, sampler3DMSArray | 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray, image3DMSArray | image2DMSArray, image3DMSArray | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| samplerCubeArray | cube map array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageCubeArray | imageCubeArray | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler2DShadow | 1D or 2D depth texture with comparison | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DShadow | image2DShadow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| sampler3DShadow | 3D depth texture with comparison | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image3DShadow | image3DShadow | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| <h4>Signed Integer Opaque Types (cont'd)</h4> <table> <tr> <td>image2DRect</td><td>int, 2D rectangular image</td></tr> <tr> <td>image1DArray</td><td>integer 1D, 2D array texture</td></tr> <tr> <td>image2DArray</td><td>integer 2D, 3D array texture</td></tr> <tr> <td>imageBuffer</td><td>integer buffer texture</td></tr> <tr> <td>imageBuffer</td><td>integer buffer texture</td></tr> <tr> <td>imageBuffer</td><td>integer buffer texture</td></tr> <tr> <td>image2DMS</td><td>int, 2D multi-sample texture</td></tr> <tr> <td>image2DMS</td><td>int, 2D multi-sample texture</td></tr> <tr> <td>image2DMSArray</td><td>int, 2D multi-sample array texture</td></tr> <tr> <td>image2DMSArray</td><td>int, 2D multi-sample array texture</td></tr> <tr> <td>image2DMSArray</td><td>int, 2D multi-sample array texture</td></tr> <tr> <td>imageCubeArray</td><td>int, cube map array texture</td></tr> <tr> <td>imageCubeArray</td><td>int, cube map array texture</td></tr> </table> <h4>Unsigned Integer Opaque Types (cont'd)</h4> <table> <tr> <td>image2DRect</td><td>uint, 2D rectangular image</td></tr> <tr> <td>image1DArray</td><td>uint, 1D, 2D array texture</td></tr> <tr> <td>image2DArray</td><td>uint, 2D, 3D array texture</td></tr> <tr> <td>imageBuffer</td><td>uint, buffer texture</td></tr> <tr> <td>imageBuffer</td><td>uint, buffer texture</td></tr> <tr> <td>imageBuffer</td><td>uint, buffer texture</td></tr> <tr> <td>image2DMS</td><td>uint, 2D multi-sample texture</td></tr> <tr> <td>image2DMS</td><td>uint, 2D multi-sample texture</td></tr> <tr> <td>image2DMSArray</td><td>uint, 2D multi-sample array texture</td></tr> <tr> <td>image2DMSArray</td><td>uint, 2D multi-sample array texture</td></tr> <tr> <td>image2DMSArray</td><td>uint, 2D multi-sample array texture</td></tr> <tr> <td>imageCubeArray</td><td>uint, cube map array texture</td></tr> <tr> <td>imageCubeArray</td><td>uint, cube map array texture</td></tr> </table> | | image2DRect | int, 2D rectangular image | image1DArray | integer 1D, 2D array texture | image2DArray | integer 2D, 3D array texture | imageBuffer | integer buffer texture | imageBuffer | integer buffer texture | imageBuffer | integer buffer texture | image2DMS | int, 2D multi-sample texture | image2DMS | int, 2D multi-sample texture | image2DMSArray | int, 2D multi-sample array texture | image2DMSArray | int, 2D multi-sample array texture | image2DMSArray | int, 2D multi-sample array texture | imageCubeArray | int, cube map array texture | imageCubeArray | int, cube map array texture | image2DRect | uint, 2D rectangular image | image1DArray | uint, 1D, 2D array texture | image2DArray | uint, 2D, 3D array texture | imageBuffer | uint, buffer texture | imageBuffer | uint, buffer texture | imageBuffer | uint, buffer texture | image2DMS | uint, 2D multi-sample texture | image2DMS | uint, 2D multi-sample texture | image2DMSArray | uint, 2D multi-sample array texture | image2DMSArray | uint, 2D multi-sample array texture | image2DMSArray | uint, 2D multi-sample array texture | imageCubeArray | uint, cube map array texture | imageCubeArray | uint, cube map array texture | <h4>Implicit Conversions</h4> <table> <tr> <td>int</td><td>→</td><td>uint</td></tr> <tr> <td>int, uint</td><td>→</td><td>float</td></tr> <tr> <td>int, uint, float</td><td>→</td><td>double</td></tr> <tr> <td>vec2</td><td>→</td><td>vec3</td></tr> <tr> <td>vec3</td><td>→</td><td>vec4</td></tr> <tr> <td>vec4</td><td>→</td><td>vec5</td></tr> <tr> <td>vec5</td><td>→</td><td>vec6</td></tr> <tr> <td>vec6</td><td>→</td><td>vec7</td></tr> <tr> <td>vec7</td><td>→</td><td>vec8</td></tr> <tr> <td>vec8</td><td>→</td><td>vec9</td></tr> <tr> <td>vec9</td><td>→</td><td>vec10</td></tr> <tr> <td>vec10</td><td>→</td><td>vec11</td></tr> <tr> <td>vec11</td><td>→</td><td>vec12</td></tr> <tr> <td>vec12</td><td>→</td><td>vec13</td></tr> <tr> <td>vec13</td><td>→</td><td>vec14</td></tr> <tr> <td>vec14</td><td>→</td><td>vec15</td></tr> <tr> <td>vec15</td><td>→</td><td>vec16</td></tr> <tr> <td>vec16</td><td>→</td><td>vec17</td></tr> <tr> <td>vec17</td><td>→</td><td>vec18</td></tr> <tr> <td>vec18</td><td>→</td><td>vec19</td></tr> <tr> <td>vec19</td><td>→</td><td>vec20</td></tr> <tr> <td>vec20</td><td>→</td><td>vec21</td></tr> <tr> <td>vec21</td><td>→</td><td>vec22</td></tr> <tr> <td>vec22</td><td>→</td><td>vec23</td></tr> <tr> <td>vec23</td><td>→</td><td>vec24</td></tr></table> | int | → | uint | int, uint | → | float | int, uint, float | → | double | vec2 | → | vec3 | vec3 | → | vec4 | vec4 | → | vec5 | vec5 | → | vec6 | vec6 | → | vec7 | vec7 | → | vec8 | vec8 | → | vec9 | vec9 | → | vec10 | vec10 | → | vec11 | vec11 | → | vec12 | vec12 | → | vec13 | vec13 | → | vec14 | vec14 | → | vec15 | vec15 | → | vec16 | vec16 | → | vec17 | vec17 | → | vec18 | vec18 | → | vec19 | vec19 | → | vec20 | vec20 | → | vec21 | vec21 | → | vec22 | vec22 | → | vec23 | vec23 | → | vec24 |
| image2DRect | int, 2D rectangular image | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image1DArray | integer 1D, 2D array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DArray | integer 2D, 3D array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | integer buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | integer buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | integer buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMS | int, 2D multi-sample texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMS | int, 2D multi-sample texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray | int, 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray | int, 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray | int, 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageCubeArray | int, cube map array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageCubeArray | int, cube map array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DRect | uint, 2D rectangular image | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image1DArray | uint, 1D, 2D array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DArray | uint, 2D, 3D array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | uint, buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | uint, buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageBuffer | uint, buffer texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMS | uint, 2D multi-sample texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMS | uint, 2D multi-sample texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray | uint, 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray | uint, 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| image2DMSArray | uint, 2D multi-sample array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageCubeArray | uint, cube map array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| imageCubeArray | uint, cube map array texture | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| int | → | uint | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| int, uint | → | float | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| int, uint, float | → | double | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec2 | → | vec3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec3 | → | vec4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec4 | → | vec5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec5 | → | vec6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec6 | → | vec7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec7 | → | vec8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec8 | → | vec9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec9 | → | vec10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec10 | → | vec11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec11 | → | vec12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec12 | → | vec13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec13 | → | vec14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec14 | → | vec15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec15 | → | vec16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec16 | → | vec17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec17 | → | vec18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec18 | → | vec19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec19 | → | vec20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec20 | → | vec21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec21 | → | vec22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec22 | → | vec23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| vec23 | → | vec24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

see www.opengl.org/sdk/docs/reference_card/opengl44-quick-reference-card.pdf

GLSL Syntax Overview

- GLSL is like C without
 - Pointers
 - Recursion
 - Dynamic memory allocation
- GLSL is like C with
 - Built-in vector, matrix and sampler types
 - Constructors
 - A math library
 - Input and output qualifiers

GLSL Syntax Overview

- GLSL has a preprocessor

```
#version 330
#ifdef FAST_EXACT_METHOD
    FastExact();
#else
    SlowApproximate();
#endif
```

- All shaders have main()

```
void main() {
    ...
}
```

Vectors

- Scalar types: **float**, **int**, **uint**, and **bool**
- Vectors are also built-in types:
 - **vec2**, **vec3**, and **vec4**
 - Also **ivec***, **uvec***, and **bvec***
- Access components three ways:
 - `.x, .y, .z, .w` ← position or direction
 - `.r, .g, .b, .a` ← color
 - `.s, .t, .p, .q` ← texture coordinate

Vectors

- Vectors have constructors

```
vec3 xyz = vec3(1.0, 2.0, 3.0);
```

```
vec3 xyz = vec3(1.0); // [1.0, 1.0, 1.0]
```

```
vec3 xyz = (vec3)1.0; // error
```

```
vec3 xyz = vec3(vec2(1.0, 2.0), 3.0);
```

Swizzling

- Swizzle: select or rearrange components

```
vec4 c = vec4(0.5, 1.0, 0.8, 1.0);

vec3 rgb = c.rgb;    // [0.5, 1.0, 0.8]
      rgb = c.xyz;    // same thing! [0.5, 1.0, 0.8]
vec3 bgr = c.bgr;    // [0.8, 1.0, 0.5]

vec3 rrr = c.rrr;    // [0.5, 0.5, 0.5]

c.a = 0.5;            // [0.5, 1.0, 0.8, 0.5]
c.rb = vec2(0.0);      // [0.0, 1.0, 0.0, 0.5]

float g = rgb[1];     // 0.5, indexing, not swizzling
```

Matrices

- Matrices are built-in types:
 - Square: `mat2`, `mat3`, and `mat4`
 - Rectangular: `matmxn`. `m` columns, `n` rows
 - `mat2x3`
- Stored column major

Matrices

- Matrix Constructors

```
mat3 i = mat3(1.0); // 3x3 identity matrix  
  
mat2 m = mat2(1.0, 2.0, // [1.0 3.0] column major!  
              3.0, 4.0); // [2.0 4.0]
```

- Accessing Elements

```
float f = m[column][row]; // m some 3x3 matrix  
  
float x = m[0].x; // x component of first column  
  
vec2 yz = m[1].yz; // yz components of second column
```

Vectors and Matrices

- Matrix and vector operations are easy and fast:

```
vec3 xyz = // ...

vec3 v0 = 2.0 * xyz;           // scale
vec3 v1 = v0 + xyz;           // component-wise
vec3 v2 = v0 * xyz;           // component-wise

mat3 m = mat3(v0, v1, v2);    // give columns
mat3 m2 = mat3(2.0);          // diagonal all 2's

mat3 m3 = 3.0 * m;            // scale a matrix
mat3 mm2 = m * m2;            // matrix * matrix
vec3 xyz2 = mm2 * xyz;        // matrix * vector
```

Built-in Functions

- Selected Trigonometry Functions

```
float s = sin(theta);  
float c = cos(theta);  
float t = tan(theta);  
  
float as = asin(theta);  
  
vec3 angles = vec3(/* ... */);  
vec3 vs = sin(angles); //vector version
```

Built-in Functions

- Exponential Functions

```
float xToTheY = pow(x, y);  
float eToTheX = exp(x);  
float twoToTheX = exp2(x);  
  
float l = log(x);    // ln  
float l2 = log2(x);  // log2  
  
float s = sqrt(x);  
float is = inversesqrt(x); // single GPU instr.
```

Built-in Functions

- Selected Common Functions

```
float ax = abs(x); // absolute value
float sx = sign(x); // -1.0, 0.0, 1.0

float m0 = min(x, y); // minimum value
float m1 = max(x, y); // maximum value
float c  = clamp(x, 0.0, 1.0);

// many others: floor(), ceil(),
// step(), smoothstep(), ...
```

Built-in Functions

- Rewrite with one function call

```
float minimum = // ...  
float maximum = // ...  
float x = // ...  
  
float f = min(max(x, minimum), maximum);  
  
float f = clamp(x, minimum, maximum);
```

Built-in Functions

- Rewrite this without the **if** statement

```
float x = // ...
float f;

if (x > 0.0) {
    f = 2.0;
}
else {
    f = -2.0;
}

f = 2.0 * sign(x);
```

Built-in Functions

- Rewrite this without the **if** statement

```
float root1 = // ...
float root2 = // ...

if (root1 < root2) {
    return vec3(0.0, 0.0, root1);
}
else {
    return vec3(0.0, 0.0, root2);
}

return vec3(0.0, 0.0, min(root1, root2));
```


Built-in Functions

- Selected Geometric Functions

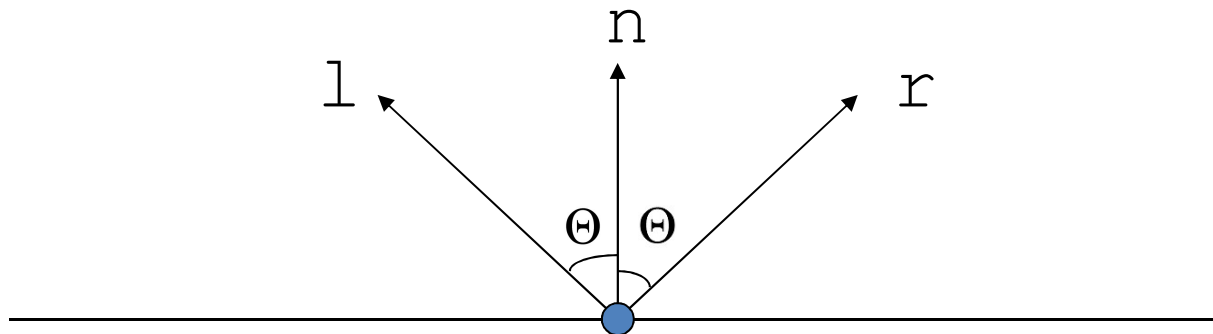
```
vec3 l = // ...
vec3 n = // ...
vec3 p = // ...
vec3 q = // ...

float f = length(l); // vector length
float d = distance(p, q); // point dist.
float d2 = dot(l, n); // dot product
vec3 v2 = cross(l, n); // cross product
vec3 v3 = normalize(l); // normalize
vec3 v3 = reflect(l, n); // reflect

// also: faceforward() and refract()
```

Built-in Functions

- **reflect** ($-l, n$)
 - Given l and n , find r
 - Angle in = angle out



Built-in Functions

- Rewrite without **length**

```
vec3 p = // ...  
vec3 q = // ...  
  
vec3 v = length(p - q);  
  
vec3 v = distance(p, q);
```

Built-in Functions

- What is wrong with this code?

```
vec3 n = // ...  
normalize(n);
```

Built-in Functions

- Selected Matrix Functions

```
mat4 m = // ...  
  
mat4 t = transpose(m) ;  
float d = determinant(m) ;  
mat4 d = inverse(m) ;
```

Built-in Functions

- Selected Vector Relational Functions

```
vec3 p = vec3(1.0, 2.0, 3.0);  
vec3 q = vec3(3.0, 2.0, 1.0);  
  
bvec3 b = equal(p, q);           // (false, true, false)  
bvec3 b2 = lessThan(p, q);       // (true, false, false)  
bvec3 b3 = greaterThan(p, q);    // (false, false, true)  
  
bool b4 = any(b);                // true  
bool b5 = all(b);                // false
```

Built-in Functions

- Rewrite this in one line of code

```
bool foo(vec3 p, vec3 q) {  
    if (p.x < q.x) {  
        return true;  
    }  
    else if (p.y < q.y) {  
        return true;  
    }  
    else if (p.z < q.z) {  
        return true;  
    }  
    return false;  
}  
return any(lessThan(p, q));
```

Samplers

- *Opaque* types for accessing textures
- Always **uniform**

```
// fragment shader
uniform sampler2D colorMap; // 2D texture

vec3 color = texture(colorMap, vec2(0.5, 0.5)).rgb;

vec2 size = textureSize(colorMap, 0);

// Lots of sampler types: sampler1D,
// sampler3D, sampler2DRect, samplerCube,
// isampler*, usampler*, ...
// Lots of sampler functions: texelFetch, textureLod
```


Samplers

- Returns **vec4**
- Coordinate access differs by sampler type

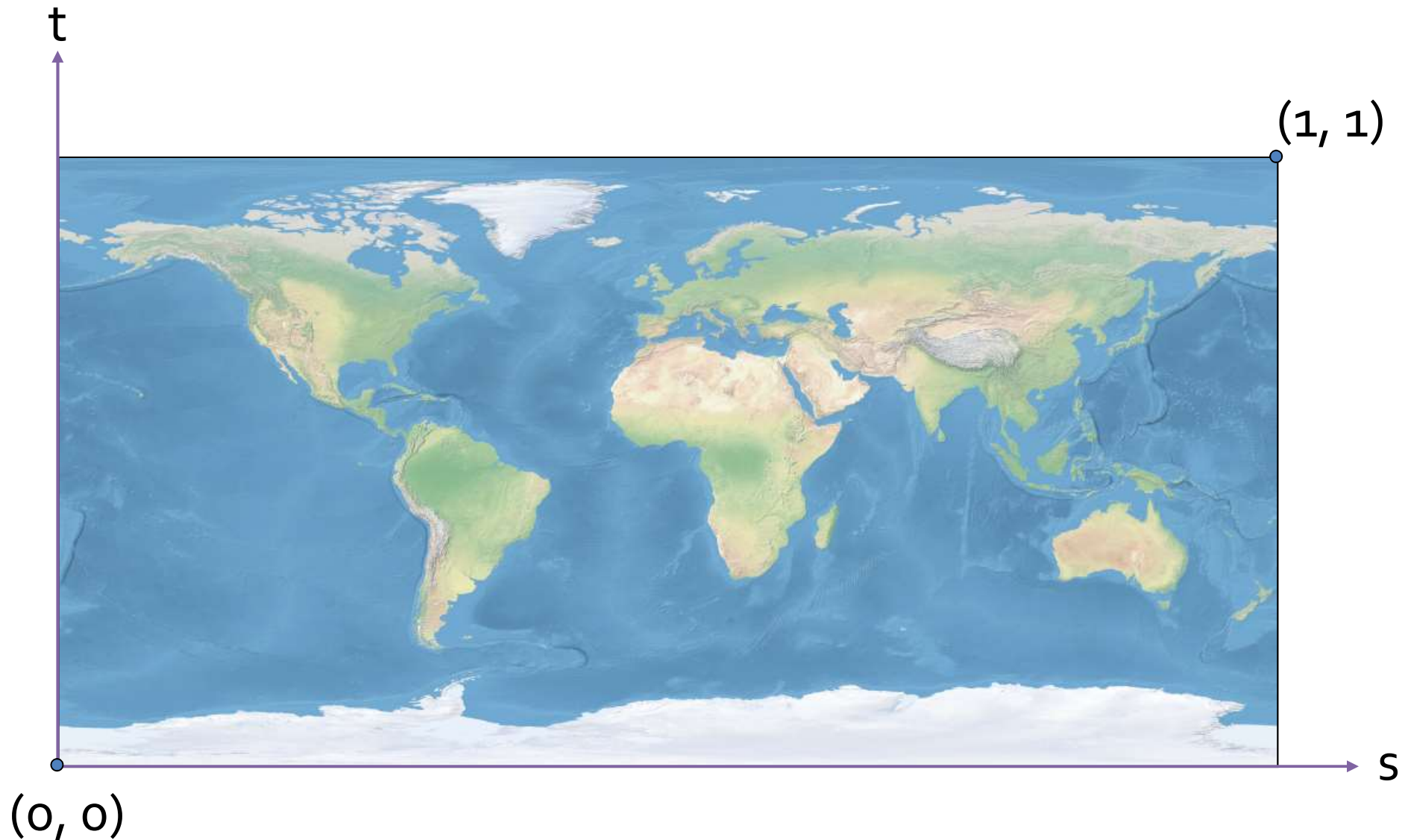
```
// fragment shader
uniform sampler2D colorMap; // 2D texture

vec3 color = texture(colorMap, vec2(0.5, 0.5)).rgb;

vec2 size = textureSize(colorMap, 0);

// Lots of sampler types: sampler1D,
// sampler3D, sampler2DRect, samplerCube,
// isampler*, usampler*, ...
// Lots of sampler functions: texelFetch, textureLod
```

Samplers – Texture Coordinates



Images from: <http://www.naturalearthdata.com/>