

# Effective OpenGL

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## 0. Cross platform support

Initially released on January 1992, OpenGL has a long history which led to many versions; market specific variations such as OpenGL ES in July 2003 and WebGL in 2011; a backward compatibility break with OpenGL core profile in August 2009; and many vendor specifics, multi vendors, standard, and cross API extensions.

OpenGL is massively cross platform but it doesn't mean it comes automatically. Just like C and C++ languages, it allows cross platform support but we have to work hard for it. The amount of work depends on the range of the application targeted market. Across vendors? Eg: Across AMD, ARM, Intel, NVIDIA, PowerVR and Qualcomm GPUs. Across hardware generations? Eg: Tesla, Fermi, Kepler, Maxwell and Pascal architectures. Across platforms? Eg: macOS, Linux and Windows or Android and iOS. Across languages? Eg: C with OpenGL ES and Javascript with WebGL.

Before the early 90s, vendor specific graphics APIs were the norm. However, these days, vendor specific graphics APIs are essentially either business decisions. For example, in my opinion, Metal is design to lock developers to the Apple ecosystem and DirectX 12 is a tool to force users to upgrade to Windows 10. Only in rare cases, such as Playstation libgdm, vendor specific graphics APIs are actually designed for the purpose of providing better performance.

A consequence of using vendor specific graphics APIs is that the applications are cutting out a part of the possible market share. Metal or DirectX based software won't run on Android or Linux respectively. However, this might be just fine for the purpose of the software or the company success. For example, PC gaming basically doesn't exist outside of Windows, so why bothering using another API than DirectX? Similarly, the movie industry is massively dominated by Linux and NVIDIA GPUs so why not using OpenGL like a vendor specific graphics API? Certainly, vendor specific OpenGL extensions are also designed for this purpose.

In many cases, the multiplatform design of OpenGL is just not enough as OpenGL support is controlled by the platform vendors. For example, Apple develops the macOS OpenGL driver which is both crippled and outdated. This result in no compute shader available on macOS with OpenGL due the support being limited to OpenGL 4.1. The GPU vendors have OpenGL 4.3 drivers with compute support however they can't make their drivers available on macOS due to Apple control. As a result, we have to use Metal on macOS for compute shaders. Another example, OpenGL is simply not available on Playstation 4. Last example, drivers are simply not updated on any Android devices but the ones from Google and NVIDIA. Despite, new versions of OpenGL ES or new extensions being released, these devices are never going to get the opportunity to expose these new features. For many software, there is just no other choice than supporting multiple graphics APIs.

This document is built from experiences with OpenGL to ship cross-platform software. It is designed to assist the community to use functionalities where we need them.

## 1. Internal texture formats

OpenGL expresses the texture format through the *internal format* and the *external format* which is composed of the *format* and the *type* as `glTexImage2D` declaration illustrates:

```
glTexImage2D(GLenum target, GLint level,
             GLint internalformat, GLsizei width, GLsizei height, GLint border,
             GLenum format, GLenum type, const void* pixels);
```

*Listing 1.1: Internal and external formats using glTexImage2D*

The internal format is the format of the actual storage on the device while the external format is the format of the client storage. This API design allows the OpenGL driver to convert the external data into any internal format storage.

However, while designing OpenGL ES, the Khronos Group decided to simplify the design by forbidding texture conversions<sup>(ES 2.0, section 3.7.1)</sup> and allowing the actual internal storage to be platform dependent to ensure a larger hardware ecosystem support. As a result, it is specified in OpenGL ES 2.0 that the **internalformat** argument must match the **format** argument.

```
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, Width, Height, 0, GL_RGBA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 1.2: OpenGL ES loading of a RGBA8 image*

This approach is also supported by OpenGL compatibility profile however it will generate an OpenGL error with OpenGL core profile which requires sized internal formats.

```
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA8, Width, Height, 0, GL_RGBA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 1.3: OpenGL core profile and OpenGL ES 3.0 loading of a RGBA8 image*

Additionally, texture storage (GL 4.2 / GL\_ARB\_texture\_storage and ES 3.0 / GL\_EXT\_texture\_storage) requires using sized internal formats as well.

```
glTexStorage2D(GL_TEXTURE_2D, 1, GL_RGBA8, Width, Height);
glTexSubImage2D(GL_TEXTURE_2D, 0, 0, 0, Width, Height, GL_RGBA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 1.4: Texture storage allocation and upload of a RGBA8 image*

### Sized internal format support:

- Texture storage API
- OpenGL core and compatibility profile
- OpenGL ES 3.0
- WebGL 2.0

### Unsized internal format support:

- OpenGL compatibility profile
- OpenGL ES
- WebGL

## 2. Configurable texture swizzling

OpenGL provides a mechanism to swizzle the components of a texture before they are returned to the shader. For example, it allows loading a BGRA8 or ARGB8 client texture to OpenGL RGBA8 texture object without a reordering of the CPU data.

This functionality was introduced with GL\_EXT\_texture\_swizzle later promoted to OpenGL 3.3 specification through GL\_ARB\_texture\_swizzle extension and included in OpenGL ES 3.0.

With OpenGL 3.3 and OpenGL ES 3.0, loading a BGRA8 texture can be done using the following approach shown in listing 2.1.

```
GLint const Swizzle[] = {GL_BLUE, GL_GREEN, GL_RED, GL_ALPHA};
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_R, Swizzle[0]);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_G, Swizzle[1]);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_B, Swizzle[2]);
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_A, Swizzle[3]);
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA8, Width, Height, 0, GL_RGBA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 2.1: OpenGL 3.3 and OpenGL ES 3.0 BGRA texture swizzling, a channel at a time*

Alternatively, OpenGL 3.3, GL\_ARB\_texture\_swizzle and GL\_EXT\_texture\_swizzle provides a slightly different approach allowing to setup all components at once as shown in listing 2.2.

```
GLint const Swizzle[] = {GL_BLUE, GL_GREEN, GL_RED, GL_ALPHA};
glTexParameteriv(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_RGBA, Swizzle);
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA8, Width, Height, 0, GL_RGBA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 2.2: OpenGL 3.3 BGRA texture swizzling, all channels at once:*

Unfortunately, neither WebGL 1.0 or WebGL 2.0 support texture swizzle due to the performance impact that implementing such feature on top of Direct3D would have.

### Support:

- Any OpenGL 3.3 or OpenGL ES 3.0 driver
- MacOSX 10.8 through GL\_ARB\_texture\_swizzle using the OpenGL 3.2 core driver
- Intel SandyBridge through GL\_EXT\_texture\_swizzle

### 3. BGRA texture swizzling using texture formats

OpenGL supports `GL_BGRA` external format to load BGRA8 source textures without requiring the application to swizzle the client data. This is done using the following code:

```
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA8, Width, Height, 0, GL_BGRA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 3.1: OpenGL core and compatibility profiles BGRA swizzling with texture image*

```
glTexStorage2D(GL_TEXTURE_2D, 1, GL_RGBA8, Width, Height);  
glTexSubImage2D(GL_TEXTURE_2D, 0, 0, 0, Width, Height, GL_BGRA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 3.2: OpenGL core and compatibility profiles BGRA swizzling with texture storage*

This functionality isn't available with OpenGL ES. While, it's not useful for OpenGL ES 3.0 that has [texture swizzling support](#), OpenGL ES 2.0 relies on some extensions to expose this feature however it exposed differently than OpenGL because by design, OpenGL ES doesn't support [format conversions](#) including component swizzling.

Using the [GL\\_EXT\\_texture\\_format\\_BGRA8888](#) or [GL\\_APPLE\\_texture\\_format\\_BGRA8888](#) extensions, loading BGRA textures is done with the code in listing 3.3.

```
glTexImage2D(GL_TEXTURE_2D, 0, GL_BGRA_EXT, Width, Height, 0, GL_BGRA_EXT, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 3.3: OpenGL ES BGRA swizzling with texture image*

Additional when relying on `GL_EXT_texture_storage` (ES2), BGRA texture loading requires sized internal format as shown by listing 3.4.

```
glTexStorage2D(GL_TEXTURE_2D, 1, GL_BGRA8_EXT, Width, Height);  
glTexSubImage2D(GL_TEXTURE_2D, 0, 0, 0, Width, Height, GL_BGRA, GL_UNSIGNED_BYTE, Pixels);
```

*Listing 3.4: OpenGL ES BGRA swizzling with texture storage*

#### Support:

- [Any driver supporting OpenGL 1.2 or GL\\_EXT\\_bgra including OpenGL core profile](#)
- [Adreno 200, Mali 400, PowerVR series 5, Tegra 3, Videocore IV and GC1000 through GL\\_EXT\\_texture\\_format\\_BGRA8888](#)
- [iOS and GC1000 through GL\\_APPLE\\_texture\\_format\\_BGRA8888](#)
- [PowerVR series 5 through GL\\_IMG\\_texture\\_format\\_BGRA8888](#)

## 4. Texture alpha swizzling

In this section, we call a texture alpha, a single component texture which data is accessed in the shader with the alpha channel (.a, .w, .q).

With OpenGL compatibility profile, OpenGL ES and WebGL, this can be done by creating a texture with an alpha format as demonstrated in listings 4.1 and 4.2.

```
glTexImage2D(GL_TEXTURE_2D, 0, GL_ALPHA, Width, Height, 0, GL_ALPHA, GL_UNSIGNED_BYTE, Data);
```

*Listing 4.1: Allocating and loading an OpenGL ES 2.0 texture alpha*

```
glTexStorage2D(GL_TEXTURE_2D, 1, GL_ALPHA8, Width, Height);  
glTexSubImage2D(GL_TEXTURE_2D, 0, 0, 0, Width, Height, GL_ALPHA, GL_UNSIGNED_BYTE, Data);
```

*Listing 4.2: Allocating and loading an OpenGL ES 3.0 texture alpha*

Texture alpha formats have been removed in OpenGL core profile. An alternative is to rely on rg\_texture formats and texture swizzle as shown by listings 4.3 and 4.4.

```
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_R, GL_ZERO);  
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_G, GL_ZERO);  
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_B, GL_ZERO);  
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_SWIZZLE_A, GL_RED);  
glTexImage2D(GL_TEXTURE_2D, 0, GL_R8, Width, Height, 0, GL_RED, GL_UNSIGNED_BYTE, Data);
```

*Listing 4.3: OpenGL 3.3 and OpenGL ES 3.0 texture alpha*

Texture red format was introduced on desktop with OpenGL 3.0 and GL\_ARB\_texture\_rg. On OpenGL ES, it was introduced with OpenGL ES 3.0 and GL\_EXT\_texture\_rg. It is also supported by WebGL 2.0.

Unfortunately, OpenGL 3.2 core profile doesn't support either texture alpha format or texture swizzling. A possible workaround is to expend the source data to RGBA8 which consumes 4 times the memory but is necessary to support texture alpha on MacOSX 10.7.

### Support:

- [Texture red format is supported on any OpenGL 3.0 or OpenGL ES 3.0 driver](#)
- [Texture red format is supported on PowerVR series 5, Mali 600 series, Tegra and Bay Trail on Android through GL\\_EXT\\_texture\\_rg](#)
- [Texture red format is supported on iOS through GL\\_EXT\\_texture\\_rg](#)

## 5. Half type constants

Half-precision floating point data was first introduced by GL\_NV\_half\_float for vertex attribute data and exposed using the constant `GL_HALF_FLOAT_NV` whose value is `0x140B`.

This extension was promoted to GL\_ARB\_half\_float\_vertex renaming the constant to `GL_HALF_FLOAT_ARB` but keeping the same `0x140B` value. This constant was eventually reused for GL\_ARB\_half\_float\_pixel, GL\_ARB\_texture\_float and promoted to OpenGL 3.0 core specification with the name `GL_HALF_FLOAT` and the same `0x140B` value.

Unfortunately, GL\_OES\_texture\_float took a different approach and exposed the constant `GL_HALF_FLOAT_OES` with the value `0x8D61`. However, this extension never made it to OpenGL ES core specification as OpenGL ES 3.0 reused the OpenGL 3.0 value for `GL_HALF_FLOAT`. GL\_OES\_texture\_float remains particularly useful for OpenGL ES 2.0 devices and WebGL 1.0 which also has a WebGL flavor of GL\_OES\_texture\_float extension.

Finally, just like regular RGBA8 format, OpenGL ES 2.0 requires an unsized internal format for floating point formats. Listing 5.1 shows how to correctly setup the enums to create a half texture across APIs.

```
GLenum const Type = isES20 || isWebGL10 ? GL_HALF_FLOAT_OES : GL_HALF_FLOAT;
GLenum const InternalFormat = isES20 || isWebGL10 ? GL_RGBA : GL_RGBA16F;
...
// Allocation of a half storage texture image
glTexImage2D(GL_TEXTURE_2D, 0, InternalFormat, Width, Height, 0, GL_RGBA, Type, Pixels);
...
// Setup of a half storage vertex attribute
glVertexAttribPointer(POSITION, 4, Type, GL_FALSE, Stride, Offset);
```

*Listing 5.1: Multiple uses of half types with OpenGL, OpenGL ES and WebGL*

### Support:

- All OpenGL 3.0 and OpenGL ES 3.0 implementations
- OpenGL ES 2.0 and WebGL 1.0 through GL\_OES\_texture\_float extensions



## 6. Color read format queries

OpenGL allows reading back pixels on the CPU side using `glReadPixels`. However, OpenGL ES requires implementation dependent formats which have to be queried. For OpenGL ES compatibility, these queries were added to OpenGL 4.1 core specification with [GL\\_ARB\\_ES2\\_compatibility](#). When the format is expected to represent half data, we encounter enum issue discussed in [section 5](#) in a specific corner case.

Additionally, many OpenGL ES drivers don't actually support OpenGL ES 2.0 anymore. When we request an OpenGL ES 2.0 context, we get a context for the latest OpenGL ES version supported by the drivers. Hence, these OpenGL ES implementations, queries will always return `GL_HALF_FLOAT`.

To workaround this issue, listing 6.1 proposes to always check for both `GL_HALF_FLOAT` and `GL_HALF_FLOAT_OES` even when only targeting OpenGL ES 2.0.

```
GLint ReadType = DesiredType;
GLint ReadFormat = DesiredFormat;
if(HasImplementationColorRead)
{
    glGetIntegerv(GL_IMPLEMENTATION_COLOR_READ_TYPE, &ReadType);
    glGetIntegerv(GL_IMPLEMENTATION_COLOR_READ_FORMAT, &ReadFormat);
}

std::size_t ReadTypeSize = 0;
switch(ReadType){
    case GL_FLOAT:
        ReadTypeSize = 4; break;
    case GL_HALF_FLOAT:
    case GL_HALF_FLOAT_OES:
        ReadTypeSize = 2; break;
    case GL_UNSIGNED_BYTE:
        ReadTypeSize = 1; break;
    default: assert(0);
}

std::vector<unsigned char> Pixels;
Pixels.resize(components(ReadFormat) * ReadTypeSize * Width * Height);

glReadPixels(0, 0, Width, Height, ReadFormat, ReadType, &Pixels[0]);
```

*Listing 6.1: OpenGL ES 2.0 and OpenGL 4.1 color read format*

Unfortunately, a program that chooses to only target OpenGL ES 2.0 and extensions with no regard for newer versions will not possibly run correctly on OpenGL ES implementations that automatically promote the context version such as NVIDIA driver.

### Support:

- All OpenGL 4.1, OpenGL ES 2.0 and WebGL 1.0 implementations supports read format queries.
- All OpenGL implementations will perform a conversion to any desired format

## 7. sRGB texture

sRGB texture is the capability to perform sRGB to linear conversions while sampling a texture. It is a very useful feature for linear workflows.

sRGB textures have been introduced to OpenGL with GL\_EXT\_texture\_sRGB extensions later promoted to OpenGL 2.1 specification. With OpenGL ES, it has been introduced with GL\_EXT\_sRGB which was promoted to OpenGL ES 3.0 specification.

Effectively, this feature provides an internal format variation with sRGB to linear conversion for some formats: `GL_RGB8 => GL_SRGB8` ; `GL_RGBA8 => GL_SRGB8_ALPHA8`.

The alpha channel is expected to always store linear data, as a result, sRGB to linear conversions are not performed on that channel.

OpenGL ES supports one and two channels sRGB formats through GL\_EXT\_texture\_sRGB\_R8 and GL\_EXT\_texture\_sRGB\_RG8 but these extensions are not available with OpenGL. However, OpenGL compatibility profile supports GL\_SLUMINANCE8 for single channel sRGB texture format.

Why not storing directly linear data? Because the none linear property of sRGB allows increasing the resolution where it matters more of the eyes. Effectively, sRGB formats are trivial compression formats. Higher bit-rate formats are expected to have enough resolution that no sRGB variations is available.

Compressed formats have sRGB variants when there are expected to be used for non linear data. These variants are typically introduced at the same time than the compression formats are introduced. This is the case for BPTC, ASTC or ETC2 however for older compression formats, the situation is more complex.

PVRTC and PVRTC2 sRGB variants are defined in GL\_EXT\_pvrtc\_sRGB. ETC1 doesn't have a sRGB variations but `GL_ETC1_RGB8_OES` is equivalent to `GL_COMPRESSED_RGB8_ETC2`, despite using different values, which sRGB variation is `GL_COMPRESSED_SRGB8_ETC2`.

For S3TC, the sRGB variations are defined in GL\_EXT\_texture\_sRGB which is exclusively an OpenGL extensions. With OpenGL ES, only GL\_NV\_sRGB\_formats exposed sRGB S3TC formats despite many hardware, such as Intel GPUs, being capable. ATC doesn't have any sRGB support.

### Support:

- All OpenGL 2.1, OpenGL ES 3.0 and WebGL 2.0 implementations.
- sRGB R8 is supported by PowerVR 6 and Adreno 400 GPUs on Android.
- sRGB RG8 is supported by PowerVR 6 on Android.
- Adreno 200, GCXXX, Mali 4XX, PowerVR 5 and Videocore IV doesn't support sRGB textures.
- WebGL doesn't exposed sRGB S3TC, only Chrome exposes GL\_EXT\_sRGB.

### Known bugs:

- Intel OpenGL ES drivers (4352) doesn't expose sRGB S3TC formats while it's supported.
- NVIDIA ES drivers (355.00) doesn't list sRGB S3TC formats with `GL_COMPRESSED_TEXTURE_FORMATS` query.

## 8. sRGB framebuffer object

sRGB framebuffer is the capability of converting from linear to sRGB on framebuffer writes and reading converting from sRGB to linear on framebuffer read. It requires sRGB textures used as framebuffer color attachments and only apply to the sRGB color attachments. It is a very useful feature for linear workflows.

sRGB framebuffers have been introduced to OpenGL with GL\_EXT framebuffer sRGB extension later promoted to GL\_ARB framebuffer sRGB extension and into OpenGL 2.1 specification. On OpenGL ES, the functionality was introduced with GL\_EXT sRGB which was promoted to OpenGL ES 3.0 specification.

OpenGL and OpenGL ES sRGB framebuffer have few differences. With OpenGL ES, framebuffer sRGB conversion is automatically performed for framebuffer attachment using sRGB formats. With OpenGL, framebuffer sRGB conversions must be explicitly enabled:

```
glEnable(GL_FRAMEBUFFER_SRGB)
```

OpenGL ES has the GL\_EXT sRGB write control extension to control the sRGB conversion however a difference remains: With OpenGL, framebuffer sRGB conversions are disabled by default while on OpenGL ES sRGB conversions are enabled by default.

WebGL 2.0 supports sRGB framebuffer object. However, WebGL 1.0 has very limited support through GL\_EXT sRGB which is only implemented by Chrome to date.

A possibility workaround is to use a linear format framebuffer object, such as GL\_RGBA16F, and use a linear to sRGB shader to blit results to the default framebuffer. With this is a solution to allow a linear workflow, the texture data needs to be linearized offline. HDR formats are exposed in WebGL 1.0 by GL\_OES texture half float and GL\_OES texture float extensions.

With WebGL, there is no equivalent for OpenGL ES GL\_EXT sRGB write control.

### References:

- [The sRGB Learning Curve](#)
- [The Importance of Terminology and sRGB Uncertainty](#)

### Support:

- All OpenGL 2.1+, OpenGL ES 3.0 and WebGL 2.0 implementations.
- GL\_EXT sRGB is supported by Adreno 200, Tegra, Mali 60, Bay Trail.
- GL\_EXT sRGB is supported by WebGL 1.0 Chrome implementations.
- GL\_EXT sRGB write control is supported by Adreno 300, Mali 600, Tegra and Bay Trail

### Bugs:

- OSX 10.8 and older with AMD HD 6000 and older GPUs have a bug where sRGB conversions are performed even on linear framebuffer attachments if GL\_FRAMEBUFFER\_SRGB is enabled.

## 9. sRGB default framebuffer

While sRGB framebuffer object is pretty straightforward, sRGB default framebuffer is pretty complex. This is partially due to the interaction with the window system but also driver behaviors inconsistencies that is in some measure the responsibility of the specification process.

On Windows and Linux, sRGB default framebuffer is exposed by [WGL|GLX] EXT framebuffer sRGB extensions for AMD and NVIDIA implementations but on Intel and Mesa implementations, it is exposed by the promoted [WGL|GLX] ARB framebuffer sRGB extensions... which text never got written...

In theory, these extensions provide two functionalities: They allow performing sRGB conversions on the default framebuffer and provide a query to figure out whether the framebuffer is sRGB capable as shown in listing 9.1 and 9.2.

```
glGetIntegerv(GL_FRAMEBUFFER_SRGB_CAPABLE_EXT, &sRGBCapable);
```

*Listing 9.1: Using [WGL|GLX]\_EXT\_framebuffer\_sRGB, is the default framebuffer sRGB capable?*

```
glGetFramebufferAttachmentParameteriv(  
    GL_DRAW_FRAMEBUFFER, GL_BACK_LEFT,  
    GL_FRAMEBUFFER_ATTACHMENT_COLOR_ENCODING, &Encoding);
```

*Listing 9.2: Using [WGL|GLX]\_ARB\_framebuffer\_sRGB, is the default framebuffer sRGB capable?*

AMD and NVIDIA drivers support the approach from listing 9.2 but regardless the approach, AMD drivers claims the default framebuffer is sRGB while NVIDIA drivers claims it's linear. Intel implementation simply ignore the query. In practice, it's better to simply not rely on the queries, it's just not reliable.

All OpenGL implementations on desktop perform sRGB conversions when enabled with `glEnable(GL_FRAMEBUFFER_SRGB)` on the default framebuffer.

The main issue is that with Intel and NVIDIA OpenGL ES implementation on desktop, there is simply no possible way to trigger the automatic sRGB conversions on the default framebuffer. An expensive workaround is to do all the rendering into a linear framebuffer object and use an additional shader pass to manually performance the final linear to sRGB conversion. A possible format is `GL_RGB10A2` to maximum performance when the alpha channel is not useful and when we accept a slight lose of precision (sRGB has the equivalent of up to 12-bit precision for some values). Another option is `GL_RGBA16F` with a higher cost but which can come for nearly free with HDR rendering.

EGL has the EGL\_KHR\_g1\_colorspace extension to explicitly specify the default framebuffer colorspace. This is exactly what we need for CGL, WGL and GLX. HTML5 canvas doesn't support color space but there is a proposal.

### Bugs:

- Intel OpenGL ES drivers (4331) `GL_FRAMEBUFFER_ATTACHMENT_COLOR_ENCODING` query is ignored.
- NVIDIA drivers (368.22) returns `GL_LINEAR` with `GL_FRAMEBUFFER_ATTACHMENT_COLOR_ENCODING` query on the default framebuffer but perform sRGB conversions anyway.
- With OpenGL ES drivers on WGL (NVIDIA & Intel), there is no possible way to perform sRGB conversions on the default framebuffer.

## Change log

2016-06-28

- Added item 0: Cross platform support
- Added item 7: sRGB textures
- Added item 8: sRGB framebuffer objects
- Added item 9: sRGB default framebuffer

2016-06-12

- Added item 1: Internal texture formats
- Added item 2: Configurable texture swizzling
- Added item 3: BGRA texture swizzling using texture formats
- Added item 4: Texture alpha swizzling
- Added item 5: Half type constants
- Added item 6: Color read format queries