Shaders and SPIR-V

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Vulkan Shader Stages

typedef enum VkPipelineStageFlagBits {
    VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT = 0x00000001,
    VK_PIPELINE_STAGE_DRAW_INDIRECT_BIT = 0x00000002,
    VK_PIPELINE_STAGE_VERTEX_INPUT_BIT = 0x00000004,
    VK_PIPELINE_STAGE_VERTEX_SHADER_BIT = 0x00000008,
    VK_PIPELINE_STAGE_TESSELLATION_CONTROL_SHADER_BIT = 0x00000010,
    VK_PIPELINE_STAGE_TESSELLATION_EVALUATION_SHADER_BIT = 0x00000020,
    VK_PIPELINE_STAGE_GEOMETRY_SHADER_BIT = 0x00000040,
    VK_PIPELINE_STAGE_FRAGMENT_SHADER_BIT = 0x00000080,
    VK_PIPELINE_STAGE_EARLY_FRAGMENT_TESTS_BIT = 0x00000100,
    VK_PIPELINE_STAGE_LATE_FRAGMENT_TESTS_BIT = 0x00000200,
    VK_PIPELINE_STAGE_COLOR_ATTACHMENT_OUTPUT_BIT = 0x00000400,
    VK_PIPELINE_STAGE_COMPUTE_SHADER_BIT = 0x00000800,
    VK_PIPELINE_STAGE_TRANSFER_BIT = 0x00001000,
    VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT = 0x00002000,
    VK_PIPELINE_STAGE_HOST_BIT = 0x00004000,
    VK_PIPELINE_STAGE_ALL_GRAPHICS_BIT = 0x00008000,
    VK_PIPELINE_STAGE_ALL_COMMANDS_BIT = 0x00010000,
} VkPipelineStageFlagBits;

Vulkan: Creating a Pipeline

vkCreateGraphicsPipeline( )

Array naming the states that can be set dynamically

Vulkan Shader Stages

typedef enum VkPipelineStageFlagBits {
    VK_PIPELINE_STAGE_TOP_OF_PIPE_BIT = 0x00000001,
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    VK_PIPELINE_STAGE_ALL_COMMANDS_BIT = 0x00010000,
} VkPipelineStageFlagBits;
Vulkan: GLSL Differences from OpenGL

Detecting that a GLSL Shader is being used with Vulkan/SPIR-V:
- In the compiler, there is an automatic
  
  ```
  #define VULKAN 100
  ```

Vertex and Instance indices:
- `gl_VertexIndex`
- `gl_InstanceIndex`
- Both are 0-based

`gl_FragColor`:
- In OpenGL, it broadcasts to all color attachments
- In Vulkan, it just broadcasts to color attachment location #0
- Best idea: don’t use it – explicitly declare out variables to have specific location numbers

Shaders' use of Layouts for Uniform Variables

```
layout( std140, set = 0, binding = 0 ) uniform matBuf
{
  mat4 uModelMatrix;
  mat4 uViewMatrix;
  mat4 uProjectionMatrix;
  mat3 uNormalMatrix;
} Matrices;
```

All opaque (non-sampler) uniform variables must be in block buffers

Vulkan: Shader Compiling

- You pre-compile your shaders with an external compiler
- Your shaders get turned into an intermediate form known as SPIR-V
- SPIR-V gets turned into fully-compiled code at runtime
- SPIR-V spec has been public for a couple of years – new shader languages are surely being developed
- OpenGL and OpenCL will be moving to SPIR-V as well

Advantages:
1. Software vendors don’t need to ship their shader source
2. Syntax errors appear during the SPIR-V step, not during runtime
3. Software can launch faster because half of the compilation has already taken place
4. This guarantees a common front-end syntax
5. This allows for other language front-ends
The first open standard intermediate language for parallel compute and graphics:

- SPIR (Standard Portable Intermediate Representation) was initially developed for use by OpenGL and SPIR versions 1.2 and 2.0 were based on LLVM. SPIR has now evolved into a true cross-API standard that is fully defined by Khronos with native support for shader and kernel features – called SPIR-V.
- SPIR-V is the first open standard, cross-API intermediate language for natively representing parallel compute and graphics and is incorporated as part of the core specification of both OpenCL 2.1 and OpenCL 2.2 and the new Vulkan graphics and compute API.
- SPIR-V exposes the machine model for OpenCL 1.2, 2.0, 2.1, 2.2 and Vulkan - including full flow-control, and graphics and parallel constructs not supported in LLVM. SPIR-V also supports OpenCL C and OpenCL C + kernel languages as well as the GLSL shader language for Vulkan.
- SPIR-V 1.1, launched in parallel with OpenCL 2.2, now supports all the kernel language features of OpenCL C + in OpenCL 2.2, including initializer and finalizer function execution modes to support constructors and destructors. SPIR-V 1.1 also enhances the expressiveness of kernel programs by supporting named barriers, subgroup execution, and program scope pipes.
- SPIR-V is catalyzing a revolution in the language compiler ecosystem – it can split the compiler chain across multiple vendors' products, enabling high-level language front-ends to emit programs in a standardized intermediate form to be ingested by Vulkan or OpenCL drivers. For hardware vendors, ingesting SPIR-V obviates the need to build a high-level language source compiler into device drivers, significantly reducing driver complexity, and will enable a broad range of language and framework front-ends to run on diverse hardware architectures.
- For developers, using SPIR-V means that kernel source code no longer has to be directly exposed, kernel load times can be accelerated and developers can choose the use of a common language front-end, improving kernel reliability and portability across multiple hardware implementations.

SPIR-V, from the Khronos Group

https://www.khronos.org/spir

SPIR-V: Standard Portable Intermediate Representation for Vulkan


Shaderfile extensions:
- .vert Vertex
- .tess Tessellation Control
- .tese Tessellation Evaluation
- .geom Geometry
- .frag Fragment
- .comp Compute

(Can be overridden by the –S option)

-V Compile for Vulkan
-G Compile for OpenGL
-I Directory(ies) to look in for #includes
-S Specify stage rather than get it from shaderfile extension
-c Print out the maximum sizes of various properties

Windows: glslangValidator.exe
Linux: setenv LD_LIBRARY_PATH /usr/local/common/gcc-6.3.0/lib64/

You Can Run the SPIR-V Compiler on Windows from a Bash Shell

1. Click on the Microsoft Start icon
2. Type word bash

Pick one:
- Can get to your personal folders
- Does not have make

- Cannot get to your personal folders
- Does have make
Running glslangValidator.exe

You can also run SPIR-V from a Linux Shell

```
$ glslangValidator.exe -V sample-vert.vert -o sample-vert.spv
$ glslangValidator.exe -V sample-frag.frag -o sample-frag.spv
```

You can also run SPIR-V from a Linux Shell

```
glslangValidator.exe -V sample-vert.vert -o sample-vert.spv
```

Compile for Vulkan ("G" is compile for OpenGL)

The input file. The compiler determines the shader type by the file extension:

- .vert  Vertex shader
- .tccs  Tessellation Control Shader
- .tecs  Tessellation Evaluation Shader
- .geom  Geometry shader
- .frag  Fragment shader
- .comp  Compute shader

Specify the output file

Same as C/C++ -- the compiler gives you no nasty messages.

Also, if you care, the .spv files have a magic number of 0x07230203

So, if you do an od -x on the .spv file, the magic number looks like this: 0203 0723 . . .
You Can Also take a look at SPIR-V Assembly

glslangValidator.exe -V -H sample-vert.vert -o sample-vert.spv

This prints out the SPIR-V "assembly" to standard output. Other than nerd interest, there is no graphics-programming reason to look at this. 😊
This is the SPIR-V Assembly, Part III

SPIR-V: More Information

SPIR-V Tools:
http://github.com/KhronosGroup/SPIRV-Tools