Vulkan: An API for Direct GPU Control

Complex drivers cause overhead and inconsistent behavior across vendors
- Difficult to optimize
- Error handling is always active
- Full GLSL preprocessor and compiler in driver
- Different APIs for desktop / mobile

Application
Single thread per context

High-level Driver Abstraction
- Error detection
- Context management
- Memory allocation
- Full GLSL compiler
- Synchronization

GPU
A Graphics API
# Vulkan: An API for Direct GPU Control

## High-level Driver Abstraction
- Error detection
- Context management
- Memory allocation
- Full GLSL compiler
- Synchronization

## Thin Driver
- SPIR-V compiler back end

## Front-end Compiler(s)
- GLSL, HLSL etc.

## Loadable debug and validation layers

## Application
- Single thread per context

## GPU

### Application
- Memory allocation
- Thread management
- Explicit Synchronization
- Multi-threaded generation of command buffers

## GPU

### Loadable debug and validation layers

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### GPU

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## Simpler drivers - application has the best knowledge for holistic optimization - no 'driver magic'
- Explicit creation of API objects before usage - efficient, predictable execution
- Easier portability - no fighting with different vendor heuristics
- Validation and debug layers loaded only when needed
- SPIR-V intermediate language: shading language flexibility
- Unified API across mobile and desktop platforms
- Multithread / Multicore friendly
Vulkan AAA Content
Vulkan Mobile Content
New Functionality Highlights
Vulkan 1.2 Released in January

- Rolls up 23 previous released extensions into a new core API
  - Improved performance, enhanced visual quality and easier development
  - Pushes the industry toward a unified feature set and development target

Requests from Vulkan Developers
- VK_KHR_timeline_semaphore - more manageable synchronization
- VK_EXT_descriptor_indexing - reusing descriptor layouts for multiple shaders
- VK_KHR_buffer_device_address - bindless resources
- VK_KHR_imageless_framebuffer - framebuffer definition without images
- VK_EXT_host_query_reset - easier resetting of queries

API Usability Improvements
- VK_KHR_driver_properties - reports latest passing CTS version
- VK_KHR_create_renderpass2 - more extensible renderpass objects
- Vulkan 1.1/1.2 unified feature and property structs

Exposing New Hardware Capabilities
- VK_KHR_image_format_list - improve image view performance
- framebufferIntegerColorSampleCounts - more multi-sample formats
- VK_KHR_sampler_mirror_clamp_to_edge - widely supported mode
- VK_EXT_sampler_filter_minmax - for newer GPUs
- VK_EXT_shader_viewport_index_layer - for newer GPUs
- VK_KHR_shader_float16_int8 - proper fp16 support
- VK_KHR_shader_float Controls - control over rounding, etc.
- VK_KHR_vulkan_memory_model - precise memory model spec
- VK_KHR_shader_subgroup_extended_types - more subgroup types
- VK_KHR_8bit_storage - 8-bit types in SSBOs/UBOs
- VK_KHR_shader_atomic_int64
- VK_KHR_depth_stencil_resolve - resolve modes for depth/stencil

Vulkan 1.2 deliberately does not mandate new hardware functionality so that all Vulkan GPU drivers are able to be upgraded.
Vulkan Ray Tracing *(provisional specifications)*

**VK_KHR_ray_tracing**
- Build acceleration structures (AS) on host or GPU
- Cast rays via ray tracing pipelines or ray queries

**VK_KHR_pipeline_libraries**
- Assemble RT pipelines from separately compiled stages

**VK_KHR_deferred_host_operations**
- Let the driver parallelize AS or pipeline construction
- Application provides the thread pool

**Status**
- Good community / ecosystem feedback received
- Making good progress toward final specifications
Variable Rate Shading enables focusing of rendering power for more perf/less power
Shading Rate selects how many pixels’ color values are affected by each fragment
‘Spreads’ a fragment between 1 to 4 times independently on both X and Y axis

Rate Per Draw Call
Lower rate for background or low-detail objects

Rate Per Triangle (optional)
Lower rate for low-detail primitives

Rate Per Region (optional)
Lower rate for periphery

COMBINE
Keep or Replace or Min or Max (per axis) or Mul (per axis)

Specifying Shading Rate

COMBINE
Keep or Replace or Min or Max (per axis) or Mul (per axis)

Final Rate

Color overlay indicates region shading rates
Image courtesy of NVIDIA

Lower-resolution image (render pass attachment) defines a shading rate for each rectangular region
Other new functionality

Ease of use
VK_EXT_extended_dynamic_state

Debug, tooling, development
VK_EXT_device_memory_report
VK_KHR_shader_non_semantic_info
VK_EXT_tooling_info
VK_KHR_performance_query
VK_EXT_private_data
VK_EXT_pipeline_creation_cache_control
VK_EXT_pipeline_executable_properties
VK_EXT_shader_clock

Rendering functionality
VK_EXT_line_rasterization
VK_EXT_fragment_density_map2
VK_EXT_texture_compression_astc_hdr

D3D / GL / WebGPU emulation
VK_EXT_robustness2
VK_EXT_image_robustness
VK_EXT_custom_border_color
VK_EXT_4444_formats
VK_KHR_shader_terminate_invocation

Odds and ends
VK_EXT_subgroup_size_control

Improving extension documentation
• Recent extensions include a statement of intended use in the Overview
• Extensions now have their own man (7) pages
• Additional information for some extensions is in the Vulkan Guide
Ecosystem
Vulkan SDK Advances

Vulkan Synchronization Validation!
• Phase 1 released in August: memory hazard detection within a command buffer

Reimagined Vulkan Configurator (vkconfig)
• Discover, enable, and configure Vulkan Layers interactively

GFXReconstruct
• New, improved trace / replay tool: Cross-OS, compression, trimming, ...

Better error reporting in the Validation Layers
• Error messages cross-link to VUID tags in the Vulkan Specification

Ecosystem Survey
• Your feedback produces results! See the 2019 Year End Report.
• 2020 Survey results coming soon!

Vulkan Developer Resources

www.khr.io/vked
  • A curated list of educational resources

www.khr.io/awesomevk
  • Another good list of resources

www.khr.io/vksamples
  • Khronos/community managed collection of high-quality sample code

Recent blogs / videos:
  • Jet Set Vulkan: Reflecting on the move to Vulkan
  • Porting Detroit: Become Human from PlayStation® 4 to PC - Part 1
  • Vulkan Synchronization Validation Quick Start Guide
  • Optimizing Roblox: Vulkan Best Practices for Mobile Developers