The Swap Chain
How OpenGL Thinks of Framebuffers
How Vulkan Thinks of Framebuffers – the Swap Chain
What is a Swap Chain?

Vulkan does not use the idea of a “back buffer”. So, we need a place to render into before moving an image into place for viewing. The is called the **Swap Chain**.

In essence, the Swap Chain manages one or more image objects that form a sequence of images that can be drawn into and then given to the Surface to be presented to the user for viewing.

Swap Chains are arranged as a ring buffer

Swap Chains are tightly coupled to the window system.

After creating the Swap Chain in the first place, the process for using the Swap Chain is:

1. Ask the Swap Chain for an image
2. Render into it via the Command Buffer and a Queue
3. Return the image to the Swap Chain for presentation
4. Present the image to the viewer (copy to “front buffer”)

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Oregon State University Computer Graphics
We Need to Find Out What our Display Capabilities Are

```c
VkSurfaceCapabilitiesKHR vsc;
vkGetPhysicalDeviceSurfaceCapabilitiesKHR( PhysicalDevice, Surface, OUT &vsc );
VkExtent2D surfaceRes = vsc.currentExtent;
fprintf( FpDebug, "\nvkGetPhysicalDeviceSurfaceCapabilitiesKHR:\n" );

VkBool32 supported;
result = vkGetPhysicalDeviceSurfaceSupportKHR( PhysicalDevice, FindQueueFamilyThatDoesGraphics( ), Surface, &supported );
if( supported == VK_TRUE )
    fprintf( FpDebug, "** This Surface is supported by the Graphics Queue **\n" );

uint32_t formatCount;
vkGetPhysicalDeviceSurfaceFormatsKHR( PhysicalDevice, Surface, &formatCount, (VkSurfaceFormatKHR *) nullptr );
VkSurfaceFormatKHR * surfaceFormats = new VkSurfaceFormatKHR[ formatCount ];
vkGetPhysicalDeviceSurfaceFormatsKHR( PhysicalDevice, Surface, &formatCount, surfaceFormats );
fprintf( FpDebug, "Found %d Surface Formats:\n", formatCount )

uint32_t presentModeCount;
vkGetPhysicalDeviceSurfacePresentModesKHR( PhysicalDevice, Surface, &presentModeCount, (VkPresentModeKHR *) nullptr );
VkPresentModeKHR * presentModes = new VkPresentModeKHR[ presentModeCount ];
vkGetPhysicalDeviceSurfacePresentModesKHR( PhysicalDevice, Surface, &presentModeCount, presentModes );
fprintf( FpDebug, "Found %d Present Modes:\n", presentModeCount );
```

We Need to Find Out What our Display Capabilities Are
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VulkanDebug.txt output:

```
vkGetPhysicalDeviceSurfaceCapabilitiesKHR:
    minImageCount = 2 ; maxImageCount = 8
    currentExtent = 1024 x 1024
    minImageExtent = 1024 x 1024
    maxImageExtent = 1024 x 1024
    maxImageArrayLayers = 1
    supportedTransforms = 0x0001
    currentTransform = 0x0001
    supportedCompositeAlpha = 0x0001
    supportedUsageFlags = 0x009f

** This Surface is supported by the Graphics Queue **

Found 2 Surface Formats:
0:  44  0  ( VK_FORMAT_B8G8R8A8_UNORM, VK_COLOR_SPACE_SRGB_NONLINEAR_KHR )
1:  50  0  ( VK_FORMAT_B8G8R8A8_SRGB,  VK_COLOR_SPACE_SRGB_NONLINEAR_KHR )

Found 3 Present Modes:
0:  2  ( VK_PRESENT_MODE_FIFO_KHR )
1:  3  ( VK_PRESENT_MODE_FIFO_RELAXED_KHR )
2:  1  ( VK_PRESENT_MODE_MAILBOX_KHR )
```
Creating a Swap Chain

vkGetDevicePhysicalSurfaceCapabilities()

VkSurfaceCapabilities

VkSwapchainCreateInfo

surface
imageFormat
imageColorSpace
imageExtent
imageArrayLayers
imageUsage
imageSharingMode
preTransform
compositeAlpha
presentMode
clipped

minImageCount
maxImageCount
currentExtent
minImageExtent
maxImageExtent
maxImageArrayLayers
supportedTransforms
currentTransform
supportedCompositeAlpha

vkCreateSwapchain()

vkGetSwapChainImages()

vkCreateImageView()
Creating a Swap Chain

```cpp
VkSurfaceCapabilitiesKHR vsc;
vkGetPhysicalDeviceSurfaceCapabilitiesKHR( PhysicalDevice, Surface, OUT &vsc );
VkExtent2D surfaceRes = vsc.currentExtent;

VkSwapchainCreateInfoKHR vscci;
    vscci.sType = VK_STRUCTURE_TYPE_SWAPCHAIN_CREATE_INFO_KHR;
    vscci.pNext = nullptr;
    vscci.flags = 0;
    vscci.surface = Surface;
    vscci.minImageCount = 2; // double buffering
    vscci.imageFormat = VK_FORMAT_B8G8R8A8_UNORM;
    vscci.imageColorSpace = VK_COLORSPACE_SRGB_NONLINEAR_KHR;
    vscci.imageExtent.width = surfaceRes.width;
    vscci.imageExtent.height = surfaceRes.height;
    vscci.imageUsage = VK_IMAGE_USAGE_COLOR_ATTACHMENT_BIT;
    vscci.preTransform = VK_SURFACE_TRANSFORM_IDENTITY_BIT_KHR;
    vscci.compositeAlpha = VK_COMPOSITE_ALPHA_OPAQUE_BIT_KHR;
    vscci.imageArrayLayers = 1;
    vscci.imageSharingMode = VK_SHARING_MODE_EXCLUSIVE;
    vscci.queueFamilyIndexCount = 0;
    vscci.pQueueFamilyIndices = (const uint32_t *)nullptr;
    vscci.presentMode = VK_PRESENT_MODE_MAILBOX_KHR;
    vscci.oldSwapchain = VK_NULL_HANDLE;
    vscci.clipped = VK_TRUE;

result = vkCreateSwapchainKHR( LogicalDevice, IN &vscci, PALLOCATOR, OUT &SwapChain );
```
Creating the Swap Chain Images and Image Views

```c
uint32_t imageCount;               // # of display buffers – 2? 3?
result = vkGetSwapchainImagesKHR( LogicalDevice, IN SwapChain, OUT &imageCount, (VkImage *)nullptr);

PresentImages = new VkImage[ imageCount ];
result = vkGetSwapchainImagesKHR( LogicalDevice, SwapChain, OUT &imageCount, PresentImages );

// present views for the double-buffering:

PresentImageViews = new VkImageView[ imageCount ];

for( unsigned int i = 0; i < imageCount; i++ )
{
    VkImageViewCreateInfo vivci;
    vivci.sType = VK_STRUCTURE_TYPE_IMAGE_VIEW_CREATE_INFO;
    vivci.pNext = nullptr;
    vivci.flags = 0;
    vivci.viewType = VK_IMAGE_VIEW_TYPE_2D;
    vivci.format = VK_FORMAT_B8G8R8A8_UNORM;
    vivci.components.r = VK_COMPONENT_SWIZZLE_R;
    vivci.components.g = VK_COMPONENT_SWIZZLE_G;
    vivci.components.b = VK_COMPONENT_SWIZZLE_B;
    vivci.components.a = VK_COMPONENT_SWIZZLE_A;
    vivci.subresourceRange.aspectMask = VK_IMAGE_ASPECT_COLOR_BIT;
    vivci.subresourceRange.baseMipLevel = 0;
    vivci.subresourceRange.levelCount = 1;
    vivci.subresourceRange.baseArrayLayer = 0;
    vivci.subresourceRange.layerCount = 1;
    vivci.image = PresentImages[ i ];

    result = vkCreateImageView( LogicalDevice, IN &vivci, PALLOCATOR, OUT &PresentImageViews[ i ] );
}
```
Rendering into the Swap Chain, I

```c
VkSemaphoreCreateInfo vsci;
    vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
    vsci.pNext = nullptr;
    vsci.flags = 0;

VkSemaphore imageReadySemaphore;
result = vkCreateSemaphore( LogicalDevice, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore );

uint32_t nextImageIndex;
uint64_t timeout = UINT64_MAX;
vkAcquireNextImageKHR( LogicalDevice, IN SwapChain, IN timeout, IN imageReadySemaphore, 
    IN VK_NULL_HANDLE, OUT &nextImageIndex );
    ...

result = vkBeginCommandBuffer( CommandBuffers[ nextImageIndex ], IN &vcbbi );
    ...

vkCmdBeginRenderPass( CommandBuffers[ nextImageIndex ], IN &vrpbi, 
    IN VK_SUBPASS_CONTENTS_INLINE );

vkCmdBindPipeline( CommandBuffers[ nextImageIndex ], VK_PIPELINE_BIND_POINT_GRAPHICS, GraphicsPipeline );
    ...

vkCmdEndRenderPass( CommandBuffers[ nextImageIndex ] );
vkEndCommandBuffer( CommandBuffers[ nextImageIndex ] );
```
Rendering into the Swap Chain, II

```
VkFenceCreateInfo vfci;
    vfci.sType = VK_STRUCTURE_TYPE_FENCE_CREATE_INFO;
    vfci.pNext = nullptr;
    vfci.flags = 0;

VkFence renderFence;
    vkCreateFence( LogicalDevice, &vfci, PALLOCATOR, OUT &renderFence );

VkQueue presentQueue;
    vkGetDeviceQueue( LogicalDevice, FindQueueFamilyThatDoesGraphics( ), 0, OUT &presentQueue );

VkSubmitInfo vsi;
    vsi.sType = VK_STRUCTURE_TYPE_SUBMIT_INFO;
    vsi.pNext = nullptr;
    vsi.waitSemaphoreCount = 1;
    vsi.pWaitSemaphores = &imageReadySemaphore;
    vsi.pWaitDstStageMask = &waitAtBottom;
    vsi.commandBufferCount = 1;
    vsi.pCommandBuffers = &CommandBuffers[ nextImageIndex ];
    vsi.signalSemaphoreCount = 0;
    vsi.pSignalSemaphores = &SemaphoreRenderFinished;

    result = vkQueueSubmit( presentQueue, 1, IN &vsi, IN renderFence );  // 1 = submitCount
```
Rendering into the Swap Chain, III

```c
result = vkWaitForFences( LogicalDevice, 1, IN &renderFence, VK_TRUE, UINT64_MAX );

VkPresentInfoKHR
  vpi.
  vpi.sType = VK_STRUCTURE_TYPE_PRESENT_INFO_KHR;
  vpi.pNext = nullptr;
  vpi.waitSemaphoreCount = 0;
  vpi.pWaitSemaphores = (VkSemaphore *)nullptr;
  vpi.swapchainCount = 1;
  vpi.pSwapchains = &SwapChain;
  vpi.pImageIndices = &nextImageIndex;
  vpi.pResults = (VkResult *) nullptr;

result = vkQueuePresentKHR( presentQueue, IN &vpi );
```