Remember the Overall Block Diagram?

Application

Instance

Instance

Physical Device

Physical Device

Physical Device

Logical Device

Logical Device

Logical Device

Logical Device

Logical Device

Command Buffer

Command Buffer

Command Buffer

Command Buffer
Where Synchronization Fits in the Overall Block Diagram

- Application
- Instance
- Physical Device
- Logical Device
- Command Buffer
- Event
- Semaphore
- Fence

Semaphores

- Indicates that a batch of commands has been processed from a queue. Basically announces “I am finished!”.
- You create one and give it to a Vulkan function which sets it. Later on, you tell another Vulkan function to wait for this semaphore to be signaled.
- You don’t end up setting, resetting, or checking the semaphore yourself.
- Semaphores must be initialized (“created”) before they can be used.
Creating a Semaphore

```c
VkSemaphoreCreateInfo vsci;
    vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
    vsci.pNext = nullptr;
    vsci.flags = 0;
VkSemaphore semaphore;
    result = vkCreateSemaphore( LogicalDevice, &vsci, PALLOCATOR, &semaphore );
```

This doesn't actually do anything with the semaphore – it just sets it up

Semaphores Example during the Render Loop

```c
VkSemaphore imageReadySemaphore;
VkSemaphoreCreateInfo vsci;
    vsci.sType = VK_STRUCTURE_TYPE_SEMAPHORE_CREATE_INFO;
    vsci.pNext = nullptr;
    vsci.flags = 0;
result = vkCreateSemaphore( LogicalDevice, &vsci, PALLOCATOR, &imageReadySemaphore );
uint32_t nextImageIndex;
    vkAcquireNextImageKHR( LogicalDevice, SwapChain, UINT64_MAX, imageReadySemaphore, VK_NULL_HANDLE, &nextImageIndex );
    ...
VkPipelineStageFlags waitAtBottomOfPipe = VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT;
VkSubmitInfo vsi;
    vsi.sType = VK_STRUCTURE_TYPE_SUBMIT_INFO;
    vsi.pNext = nullptr;
    vsi.waitSemaphoreCount = 1;
    vsi.pWaitSemaphores = &imageReadySemaphore;
    vsi.pWaitDstStageMask = &waitAtBottomOfPipe;
    vsi.commandBufferCount = 1;
    vsi.pCommandBuffers = CommandBuffers[nextImageIndex];
    vsi.signalSemaphoreCount = 0;
    vsi.pSignalSemaphores = (VkSemaphore) nullptr;
result = vkQueueSubmit( presentQueue, 1, &vsi, renderFence );
```

You do this to wait for an image to be ready to be rendered into
Fences

- Used to synchronize CPU-GPU tasks.
- Used when the host needs to wait for the device to complete something big.
- Announces that queue-submitted work is finished.
- You can un-signal, signal, test or block-while-waiting.

```c
#define VK_FENCE_CREATE_UNSIGNALED_BIT 0

VkFenceCreateInfo vfci;
vfci.sType = VK_STRUCTURE_TYPE_FENCE_CREATE_INFO;
vfci.pNext = nullptr;
vfci.flags = VK_FENCE_CREATE_UNSIGNALED_BIT; // = 0
// VK_FENCE_CREATE_SIGNALED_BIT is only other option

VkFence fence;
result = vkCreateFence( LogicalDevice, IN &vfci, PALLOCATOR, OUT &fence );

// returns to the host right away:
result = vkGetFenceStatus( LogicalDevice, IN fence );
// result = VK_SUCCESS means it has signaled
// result = VK_NOT_READY means it has not signaled

// blocks the host from executing:
result = vkWaitForFences( LogicalDevice, IN &fence, waitForAll, timeout );
// waitForAll = VK_TRUE: wait for all fences in the list
// waitForAll = VK_FALSE: wait for any one fence in the list
// timeout is a uint64_t timeout in nanoseconds (could be 0, which means to return immediately)
// timeout can be up to UINT64_MAX = 0xffffffffffffffff (= 580+ years)
// result = VK_SUCCESS means it returned because a fence (or all fences) signaled
// result = VK_TIMEOUT means it returned because the timeout was exceeded
```

Set the fence

Wait on the fence(s)
Fence Example

```c
VkFence renderFence;
vkCreateFenceLogicalDevice(vk, &vfci, PALLOCATOR, OUT &renderFence);

VkPipelineStageFlags waitAtBottom = VK_PIPELINE_STAGE_BOTTOM_OF_PIPE_BIT;

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 = (VkSemaphore) nullptr;

result = vkQueueSubmit(presentQueue, 1, IN &vsi, IN &renderFence);

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

result = vkQueuePresentKHR(presentQueue, IN &vpi); // don’t present the image until done rendering
```

Events

- Events provide even finer-grained synchronization.
- Events are a primitive that can be signaled by the host or the device.
- Can even signal at one place in the pipeline and wait for it at another place in the pipeline.
- Signaling in the pipeline means “signal me as the last piece of this draw command passes that point in the pipeline”.
- You can signal, un-signal, or test from a vk function or from a vkCmd function.
- Can wait from a vkCmd function.
Controlling Events from the Host

```c
VkEventCreateInfo veci;
veci.sType = VK_STRUCTURE_TYPE_EVENT_CREATE_INFO;
veci.pNext = nullptr;
veci.flags = 0;

VkEvent event;
result = vkCreateEvent( LogicalDevice, IN &veci, PALLOCATOR, OUT &event );
result = vkSetEvent( LogicalDevice, IN event );
result = vkResetEvent( LogicalDevice, IN event );
result = vkGetEventStatus( LogicalDevice, IN event );
```

// result = VK_EVENT_SET: signaled
// result = VK_EVENT_RESET: not signaled

Note: the host cannot block waiting for an event, but it can test for it

Controlling Events from the Device

```c
result = vkCmdSetEvent( CommandBuffer, IN event, pipelineStageBits );
result = vkCmdResetEvent( CommandBuffer, IN event, pipelineStageBits );
result = vkCmdWaitEvents( CommandBuffer, 1, &events );
```

Could be an array of events

Where signaled, where wait for the signal

Memory barriers get executed after events have been signaled

Note: the device cannot test for an event, but it can block