Remember the Overall Block Diagram?

- Application
  - Instance
    - Physical Device
      - Logical Device
        - Queue
        - Queue
        - Queue
  - Instance
    - Physical Device
      - Logical Device
        - Queue
        - Queue
        - Queue
    - Physical Device
      - Logical Device
        - Queue
        - Queue
        - Queue
    - Physical Device
      - Logical Device
        - Queue
        - Queue
        - Queue

Command Buffer
Command Buffer
Command Buffer
Semaphores

- Used to control readiness of resources within one queue or across different queues belonging to the same logical device
- You create them, and give them to a Vulkan function which sets them. Later on, you tell a Vulkan function to wait on this particular semaphore
- 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, IN &vsci, PALLOCATOR, OUT &semaphore );
```

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, IN &vsci, PALLOCATOR, OUT &imageReadySemaphore );

uint32_t nextImageIndex;
vkAcquireNextImageKHR( LogicalDevice, IN SwapChain, IN UINT64_MAX,
                        IN imageReadySemaphore, IN VK_NULL_HANDLE, OUT &nextImageIndex );

VkPipelineStageFlags waitAtBottom = 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 = &waitAtBottom;
    vsi.commandBufferCount = 1;
    vsi.pCommandBuffers = &CommandBuffers[nextImageIndex];
    vsi.signalSemaphoreCount = 0;
    vsi.pSignalSemaphores = (VkSemaphore)nullptr;

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

Could be an array of semaphores
Fences

- Used to synchronize the application with commands submitted to a queue
- Announces that queue-submitted work is finished
- Much finer control than semaphores
- 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 right away:
result = vkGetFenceStatus( LogicalDevice, IN fence );
    // result = VK_SUCCESS means it has signaled
    // result = VK_NOT_READY means it has not signaled

// blocks:
result = vkWaitForFences( LogicalDevice, 1, 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
```

Could be an array of fences
Fence Example

```c
VkFence renderFence;
vkCreateFence( LogicalDevice, &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 );
```

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 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

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

VkEvent event;
result = vkCreateEvent( LogicalDevice, IN &veci, OUT 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 CPU cannot block waiting for an event, but it can test for one

Controlling Events from the Device

result = vkCmdSetEvent( CommandBuffer, IN event, pipelineStageBits );
result = vkCmdResetEvent( CommandBuffer, IN event, pipelineStageBits );
result = vkCmdWaitEvents( CommandBuffer, 1, &event, srcPipelineStageBits, dstPipelineStageBits, memoryBarrierCount, pMemoryBarriers, bufferMemoryBarrierCount, pBufferMemoryBarriers, imageMemoryBarrierCount, pImageMemoryBarriers );

Could be an array of events
Where signaled, where wait for the signal
Memory barriers get executed after events have been signaled

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