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Data Buffers

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From the Quick Reference Card

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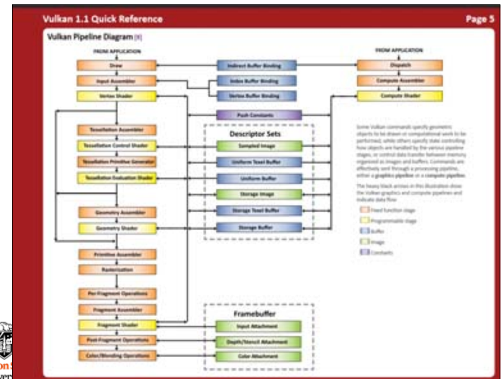

Terminology Issues

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A **Data Buffer** is just a group of contiguous bytes in GPU memory. They have no inherent meaning. The data that is stored there is whatever you want it to be. (This is sometimes called a "Binary Large Object", or "BLOB".)

It is up to you to be sure that the writer and the reader pf the Data Buffer are interpreting the bytes in the same way!

Vulkan calls these things "Buffers". But, Vulkan calls other things "Buffers", too, such as Texture Buffers and Command Buffers. So, I have taken to calling these things "Data Buffers" and have even gone to far as to override some of Vulkan's own terminology:

```
typedef VkBuffer                VkDataBuffer;
```


Vulkan: Buffers

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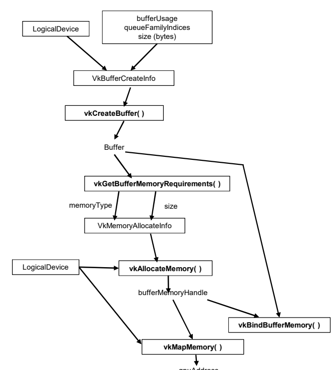

Vulkan: Creating a Data Buffer

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```
VkBufferCreateInfo  vbci;
        vbci.sType = VK_STRUCTURE_TYPE_BUFFER_CREATE_INFO;
        vbci.pNext = nullptr;
        vbci.flags = 0;
        vbci.size = << buffer size in bytes >>
        vbci.usage = <<or'ed bits of: >>
                VK_USAGE_TRANSFER_SRC_BIT
                VK_USAGE_TRANSFER_DST_BIT
                VK_USAGE_UNIFORM_TEXEL_BUFFER_BIT
                VK_USAGE_STORAGE_TEXEL_BUFFER_BIT
                VK_USAGE_UNIFORM_BUFFER_BIT
                VK_USAGE_STORAGE_BUFFER_BIT
                VK_USAGE_INDEX_BUFFER_BIT
                VK_USAGE_VERTEX_BUFFER_BIT
                VK_USAGE_INDIRECT_BUFFER_BIT
        vbci.sharingMode = << one of: >>
                VK_SHARING_MODE_EXCLUSIVE
                VK_SHARING_MODE_CONCURRENT
        vbci.queueFamilyIndexCount = 0;
        vbci.pQueueFamilyIndices = (const iont32_t) nullptr;

VkBuffer  Buffer;

result = vkCreateBuffer ( LogicalDevice, IN &vbci, PALLOCATOR,  OUT &Buffer );
```

Doesn't actually allocate memory – just creates a **VkBuffer** data structure

Vulkan: Allocating Memory for a Buffer, Binding a Buffer to Memory, and Writing to the Buffer

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```
VkMemoryRequirements                vmr;
result = vkGetBufferMemoryRequirements( LogicalDevice, Buffer, OUT &vmr );


VkMemoryAllocateInfo                vmai;
        vmai.sType = VK_STRUCTURE_TYPE_MEMORY_ALLOCATE_INFO;
        vmai.pNext = nullptr;
        vmai.flags = 0;
        vmai.allocationSize = vmr.size;
        vmai.memoryTypeIndex = FindMemoryThatIsHostVisible( );

. . .

VkDeviceMemory                vdm;
result = vkAllocateMemory( LogicalDevice, IN &vmai, PALLOCATOR,  OUT &vdm );

result = vkBindBufferMemory( LogicalDevice, Buffer, IN vdm, 0 );          // 0 is the offset

. . .

result = vkMapMemory( LogicalDevice, IN vdm, 0, VK_WHOLE_SIZE, 0, &ptr );

        << do the memory copy >>

result = vkUnmapMemory( LogicalDevice, IN vdm );
```

Finding the Right Type of Memory

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```
int
FindMemoryThatIsHostVisible( )
{
	VkPhysicalDeviceMemoryProperties	vpdmp;
	vkGetPhysicalDeviceMemoryProperties( PhysicalDevice, OUT &vpdmp );
	for( unsigned int i = 0; i < vpdmp.memoryTypeCount; i++ )
	{
		VkMemoryType vmt = vpdmp.memoryTypes[ i ];
		if( ( vmt.propertyFlags & VK_MEMORY_PROPERTY_HOST_VISIBLE_BIT ) != 0 )
		{
			return i;
		}
	}
	return -1;
}
```

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Finding the Right Type of Memory

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```
int
FindMemoryThatIsDeviceLocal( )
{
	VkPhysicalDeviceMemoryProperties	vpdmp;
	vkGetPhysicalDeviceMemoryProperties( PhysicalDevice, OUT &vpdmp );
	for( unsigned int i = 0; i < vpdmp.memoryTypeCount; i++ )
	{
		VkMemoryType vmt = vpdmp.memoryTypes[ i ];
		if( ( vmt.propertyFlags & VK_MEMORY_PROPERTY_DEVICE_LOCAL_BIT ) != 0 )
		{
			return i;
		}
	}
	return -1;
}
```

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Finding the Right Type of Memory

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```
VkPhysicalDeviceMemoryProperties			vpdmp;
vkGetPhysicalDeviceMemoryProperties( PhysicalDevice, OUT &vpdmp );
```

```
11 Memory Types:
Memory  0:
Memory  1:
Memory  2:
Memory  3:
Memory  4:
Memory  5:
Memory  6:
Memory  7:  DeviceLocal
Memory  8:  DeviceLocal
Memory  9:  HostVisible HostCoherent
Memory 10:  HostVisible HostCoherent HostCached

2 Memory Heaps:
Heap 0:  size = 0xb7c00000 DeviceLocal
Heap 1:  size = 0xfac00000
```

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Something I've Found Useful

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I find it handy to encapsulate buffer information in a struct:

```
typedef struct MyBuffer
{
	VkDataBuffer		buffer;
	VkDeviceMemory	vdm;
	VkDeviceSize		size;
} MyBuffer;

. . .

MyBuffer			MyMatrixUniformBuffer;
```

It's the usual object-oriented benefit – you can pass around just one data-item and everyone can access whatever information they need.

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Initializing a Data Buffer

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It's the usual object-oriented benefit – you can pass around just one data-item and everyone can access whatever information they need.

```
VkResult
Init05DataBuffer( VkDeviceSize size, VkBufferUsageFlags usage, OUT MyBuffer * pMyBuffer )
{
. . .
	vbci.size = pMyBuffer->size = size;
. . .
	result = vkCreateBuffer ( LogicalDevice, IN &vbci, PALLOCATOR,  OUT &pMyBuffer->buffer );
. . .
	pMyBuffer->vdm = vdm;
. . .
}
```

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Here's the C struct to hold some uniform variables

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```
struct matBuf
{
	glm::mat4 uModelMatrix;
	glm::mat4 uViewMatrix;
	glm::mat4 uProjectionMatrix;
	glm::mat3 uNormalMatrix;
} Matrices;
```

Here's the shader code to access those uniform variables

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

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Filling those Uniform Variables


```
glm::vec3  eye(0.,0.,EYEDIST);
glm::vec3  look(0.,0.,0.);
glm::vec3  up(0.,1.,0.);

Matrices.uModelMatrix      = glm::mat4( );            // identity

Matrices.uViewMatrix       = glm::lookAt( eye, look, up );

Matrices.uProjectionMatrix = glm::perspective( FOV, (double)Width/(double)Height, 0.1, 1000. );
Matrices.uProjectionMatrix[1][1] *= -1.;

Matrices.uNormalMatrix = glm::inverseTranspose(  glm::mat3( Matrices.uModelMatrix )  );
```


The Parade of Data

CPU: ***MyBuffer MyMatrixUniformBuffer;***

The MyBuffer does not hold any actual data itself. It just represents a container of data buffer information that will be used by Vulkan

```
VkResult
Init05DataBuffer( VkDeviceSize size, VkBufferUsageFlags usage, OUT MyBuffer * pMyBuffer )
{
. . .
      vbci.size = pMyBuffer->size = size;
. . .
      result = vkCreateBuffer ( LogicalDevice, IN &vbci, PALLOCATOR,  OUT &pMyBuffer->buffer );
. . .
      pMyBuffer->vdm = vdm;
. . .
}
```

This C struct is holding the actual data. It is writeable by the application.

Memory-mapped copy

The Data Buffer in GPU memory is holding the actual data. It is readable by the shaders

CPU:

struct matBuf Matrices;

```
glm::vec3  eye(0.,0.,EYEDIST);
glm::vec3  look(0.,0.,0.);
glm::vec3  up(0.,1.,0.);

Matrices.uModelMatrix      = glm::mat4( );            // identity

Matrices.uViewMatrix       = glm::lookAt( eye, look, up );

Matrices.uProjectionMatrix = glm::perspective( FOV, (double)Width/(double)Height, 0.1, 1000. );
Matrices.uProjectionMatrix[1][1] *= -1.;

Matrices.uNormalMatrix = glm::inverseTranspose(  glm::mat3( Matrices.uModelMatrix )  );
```

uniform matBuf Matrices;

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

GPU:

There is one more step in here– **Descriptor Sets**. Here's a quick preview…

The Descriptor Set for the Buffer

We will come to **Descriptor Sets** later, but for now think of them as the link between the BLOB of uniform variables in GPU memory and the block of variable names in your shader programs.

```
VkDescriptorBufferInfo                 vdbi0;
        vdbi0.buffer = MyMatrixUniformBuffer.buffer;
        vdbi0.offset = 0;      // bytes
        vdbi0.range = sizeof(Matrices);
```

```
VkWriteDescriptorSet                   vwds0;
        // ds 0:
        vwds0.sType = VK_STRUCTURE_TYPE_WRITE_DESCRIPTOR_SET;
        vwds0.pNext = nullptr;
        vwds0.dstSet = DescriptorSets[0];
        vwds0.dstBinding = 0;
        vwds0.dstArrayElement = 0;
        vwds0.descriptorCount = 1;
        vwds0.descriptorType = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
        vwds0.pBufferInfo = &vdbi0;
        vwds0.pImageInfo = (VkDescriptorImageInfo *)nullptr;
```

```
vkUpdateDescriptorSets( LogicalDevice, 1, IN &vwds0, IN 0, (VkCopyDescriptorSet *)nullptr );
```


Filling the Data Buffer


```
typedef struct MyBuffer
{
      VkDataBuffer        buffer;
      VkDeviceMemory      vdm;
      VkDeviceSize        size;
} MyBuffer;

. . .

MyBuffer                 MyMatrixUniformBuffer;
```

```
Init05UniformBuffer( sizeof(Matrices),          &MyMatrixUniformBuffer );

Fill05DataBuffer( MyMatrixUniformBuffer,      (void *) &Matrices );
```

```
glm::vec3  eye(0.,0.,EYEDIST);
glm::vec3  look(0.,0.,0.);
glm::vec3  up(0.,1.,0.);

Matrices.uModelMatrix      = glm::mat4( );            // identity

Matrices.uViewMatrix       = glm::lookAt( eye, look, up );

Matrices.uProjectionMatrix = glm::perspective( FOV, (double)Width/(double)Height, 0.1, 1000. );
Matrices.uProjectionMatrix[1][1] *= -1.;

Matrices.uNormalMatrix = glm::inverseTranspose(  glm::mat3( Matrices.uModelMatrix )  );
```


Creating and Filling the Data Buffer – the Details


```
VkResult
Init05DataBuffer( VkDeviceSize size, VkBufferUsageFlags usage, OUT MyBuffer * pMyBuffer )
{
      VkResult result = VK_SUCCESS;
      VkBufferCreateInfo  vbci;
            vbci.sType = VK_STRUCTURE_TYPE_BUFFER_CREATE_INFO;
            vbci.pNext = nullptr;
            vbci.flags = 0;
            vbci.size = pMyBuffer->size = size;
            vbci.usage = usage;
         vbci.sharingMode = VK_SHARING_MODE_EXCLUSIVE;
         vbci.queueFamilyIndexCount = 0;
            vbci.pQueueFamilyIndices = (const uint32_t *)nullptr;
      result = vkCreateBuffer ( LogicalDevice, IN &vbci, PALLOCATOR,  OUT &pMyBuffer->buffer );

      VkMemoryRequirements                 vmr;
      vkGetBufferMemoryRequirements( LogicalDevice, IN pMyBuffer->buffer, OUT &vmr );        // fills vmr

      VkMemoryAllocateInfo                 vmai;
            vmai.sType = VK_STRUCTURE_TYPE_MEMORY_ALLOCATE_INFO;
            vmai.pNext = nullptr;
            vmai.allocationSize = vmr.size;
            vmai.memoryTypeIndex = FindMemoryThatIsHostVisible( );

      VkDeviceMemory                       vdm;
      result = vkAllocateMemory( LogicalDevice, IN &vmai, PALLOCATOR, OUT &vdm );
      pMyBuffer->vdm = vdm;

      result = vkBindBufferMemory( LogicalDevice, pMyBuffer->buffer, IN vdm, 0 );            // 0 is the offset
      return result;
}
```


Copy to GPU Memory via Memory Mapping


```
VkResult
Fill05DataBuffer( IN MyBuffer myBuffer, IN void * data )
{
      // the size of the data had better match the size that was used to Init the buffer!

      void * pGpuMemory;
      vkMapMemory( LogicalDevice, IN myBuffer.vdm, 0, VK_WHOLE_SIZE, 0, OUT &pGpuMemory );
                                                                  // 0 and 0 are offset and flags
      memcpy( pGpuMemory, data, (size_t)myBuffer.size );
      vkUnmapMemory( LogicalDevice, IN myBuffer.vdm );
      return VK_SUCCESS;
}
```

Remember – to Vulkan and GPU memory, these are ***just bits***. It is up to *you* to handle their meaning correctly.