Data Buffers

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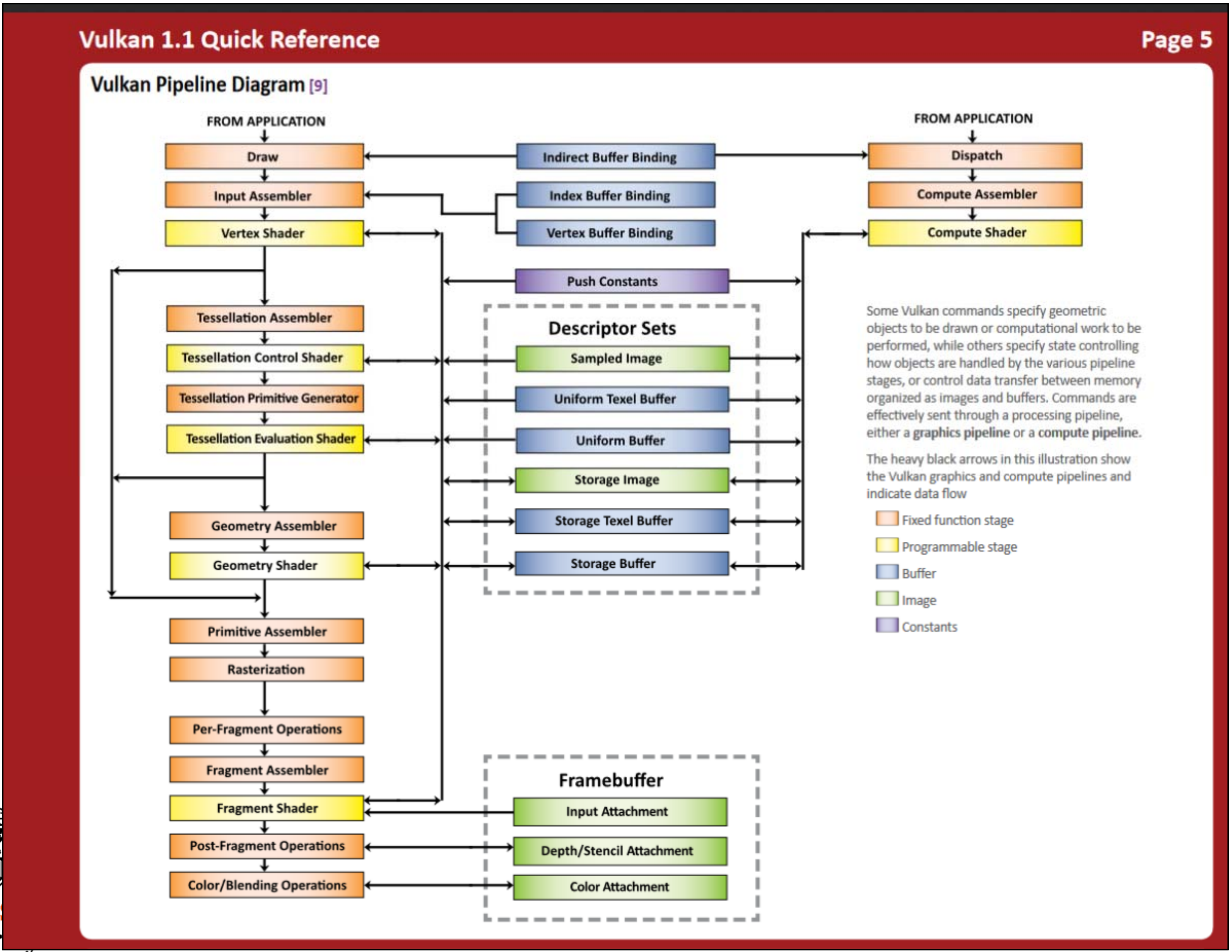
From the Quick Reference Card



Vulkan 1.1 Quick Reference

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Vulkan Pipeline Diagram [9]

Some Vulkan commands specify geometric objects to be drawn or computational work to be performed, while others specify state controlling how objects are handled by the various pipeline stages, or control data transfer between memory organized as images and buffers. Commands are effectively sent through a processing pipeline, either a **graphics pipeline** or a **compute pipeline**.

The heavy black arrows in this illustration show the Vulkan graphics and compute pipelines and indicate data flow

🟧 Fixed function stage
🟨 Programmable stage
🟦 Buffer
🟩 Image
🟪 Constants

Terminology Issues

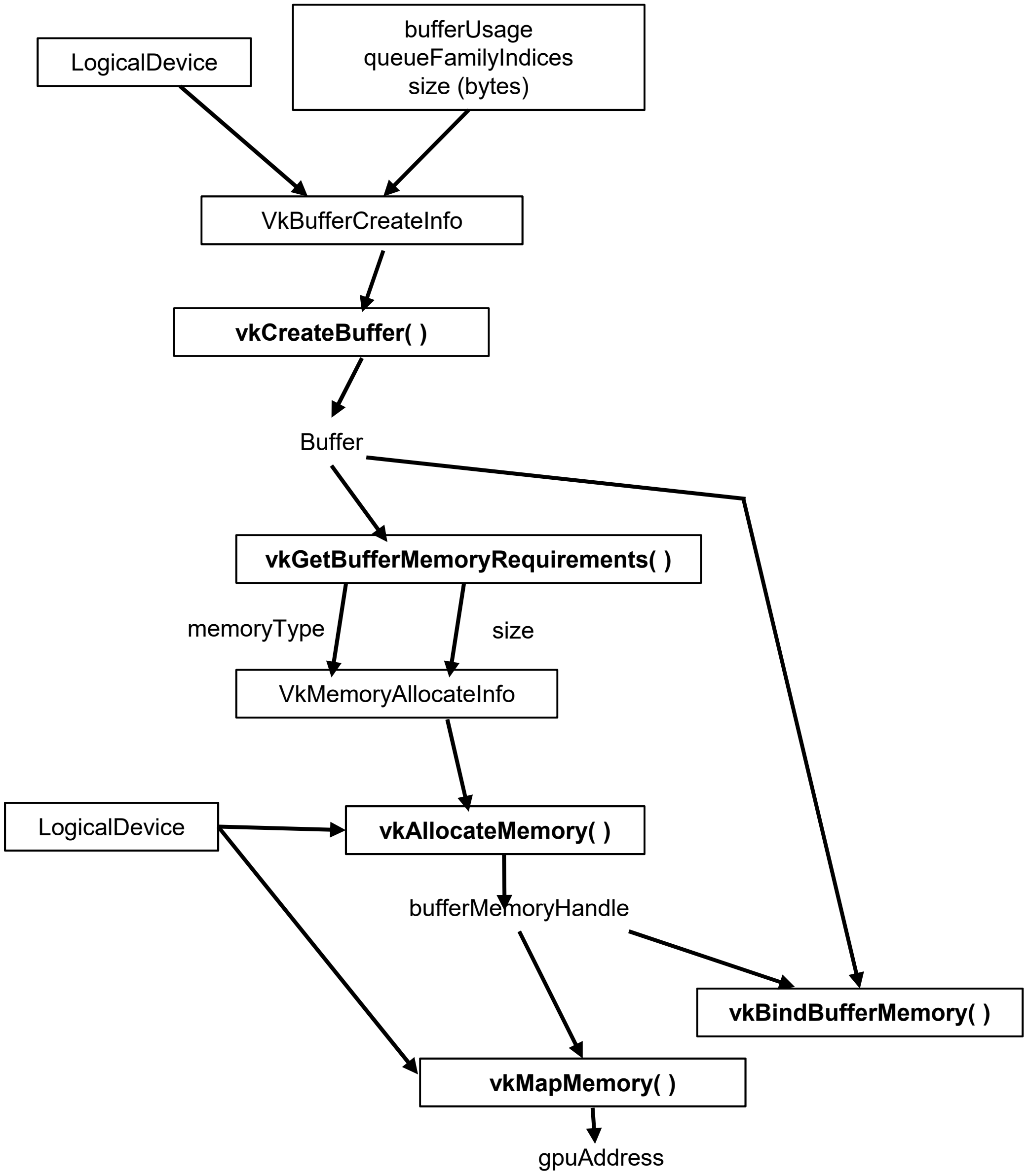
A **Data Buffer** is just a group of contiguous bytes in GPU memory. They have no inherent meaning. The data that is stored there is whatever you want it to be. (This is sometimes called a “Binary Large Object”, or “BLOB”.)

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



Vulkan: Creating a Data Buffer

```
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

```
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

```
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;
}
```

Finding the Right Type of Memory

```
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;
}
```

Finding the Right Type of Memory

```
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
```

Something I’ve Found Useful

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.

Initializing a Data Buffer

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;
. . .
}
```

Here’s the C struct to hold some uniform variables

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

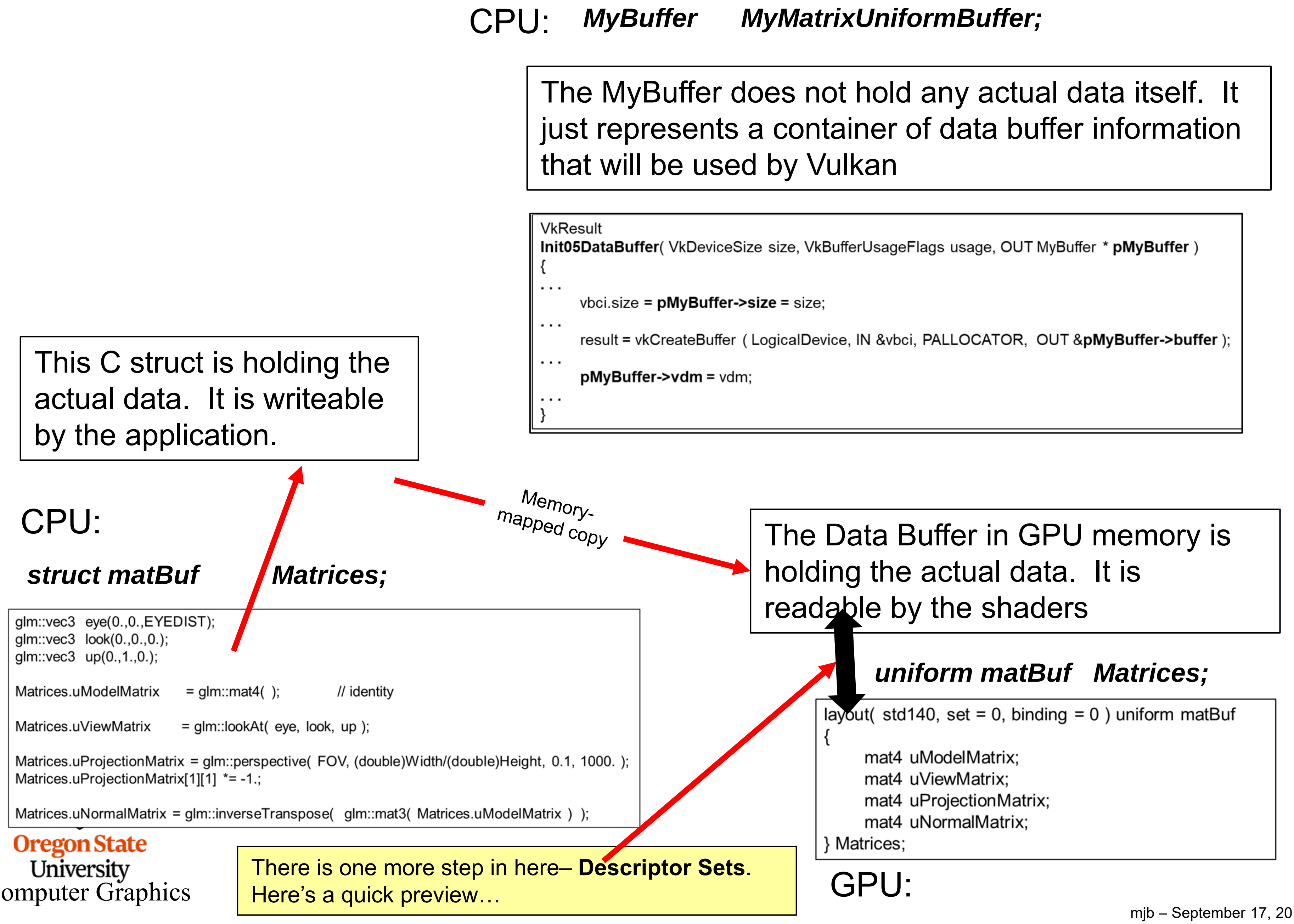
Here’s the shader code to access those uniform variables

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

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.

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 ) );
```

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

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.