Descriptor Sets

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In OpenGL

OpenGL puts all uniform data in the same "set", but with different binding numbers, so you can get at each one.

Each uniform variable gets updated one-at-a-time.

Wouldn't it be nice if we could update a bunch of related uniform variables all at once?

```
layout( std140, binding = 0 )  uniform mat4        uModelMatrix;
layout( std140, binding = 1 ) uniform mat4         uViewMatrix;
layout( std140, binding = 2 ) uniform mat4         uProjectionMatrix;
layout( std140, binding = 3 ) uniform mat3         uNormalMatrix;
layout( std140, binding = 4 ) uniform vec4          uLightPos;
layout( std140, binding = 5 ) uniform float         uTime;
layout( std140, binding = 6 ) uniform  int          uMode;
layout(             binding = 7 ) uniform sampler2D uSampler;
```

In OpenGL, these are all in one set. They all get bound, whether you need them here or not.

What are Descriptor Sets?

Descriptor Sets are an intermediate data structure that tells shaders how to connect information held in GPU memory to groups of related uniform variables and texture sampler declarations in shaders. There are three advantages in doing things this way:

1. Related uniform variables can be updated as a group, gaining efficiency.

2. Descriptor Sets are activated when the Command Buffer is filled. Different values for the uniform buffer variables can be toggled by just swapping out the Descriptor Set that points to GPU memory, rather than re-writing the GPU memory.

3. Values for the shaders' uniform buffer variables can be compartmentalized into what quantities change often and what change seldom (scene-level, model-level, draw-level), so that uniform variables need to be re-written no more often than is necessary.

```
for( each scene )
{
        Bind Descriptor Set #0
        for( each object )
        {
                Bind Descriptor Set #1
                for( each draw )
                {
                        Bind Descriptor Set #2
                        Do the drawing
                }
        }
}
```


Descriptor Sets

Our example will assume the following shader uniform variables:

```
// non-opaque must be in a uniform block:
layout( std140, set = 0, binding = 0 ) uniform matBuf
{
      mat4 uModelMatrix;
      mat4 uViewMatrix;
      mat4 uProjectionMatrix;
      mat3 uNormalMatrix;
} Matrices;

layout( std140, set = 1, binding = 0 ) uniform lightBuf
{
       float  uKa, uKd, uKs, uShininess;
       vec4 uLightPos;
       vec4 uLightSpecularColor;
       vec4 uEyePos;
} Light;


layout( std140, set = 2, binding = 0 ) uniform miscBuf
{
       float  uTime;
       int     uMode;
       int     uLighting;
} Misc;

layout( set = 3, binding = 0 ) uniform sampler2D uSampler;
```

Descriptor Sets

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CPU: Uniform data created in a C++ data structure

- Knows the CPU data structure
- Knows where the data starts
- Knows the data's size

GPU: Uniform data in a "blob"*

- Knows where the data starts
- Knows the data's size
- Doesn't know the CPU or GPU data structure

GPU: Uniform data used in the shader

- Knows the shader data structure
- Doesn't know where each piece of data starts

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

struct lightBuf
{
	float uKa, uKd, uKs, uShininess;
	glm::vec4 uLightPos;
	glm::vec4 uLightSpecularColor;
	glm::vec4 uEyePos;};

struct miscBuf
{
	float uTime;
	int   uMode
	int   uLighting;
};
```

```
10111001010101111110100010
00010111011010111101001101
10011000000111010111110011
10110100110010111111010111
00110110101000000100100011
11010001001010101010011111
11001000011100101010100011
00011011010110111111011111
1111100110101010000010
11001100100011010001 0
11001110101110100110001111
01000101000111101011111011
01110100100100011010111000
00001111100011000010000001
10110011101010001110100001
10011001100100001100000110
01111001001111010010001000
10110011100010111000000010
10000101111110101111110011
10001011100001100111101001
11100111110111011111111101
11111010011110111110101111
00101010000001111001001110
01110011111010010110011110
11001110001101100011111011
00001111100011100101100010
01110011010111011100101000
```

* "binary large object"

```
layout( std140, set = 0, binding = 0 ) uniform matBuf
{
	mat4 uModelMatrix;
	mat4 uViewMatrix;
	mat4 uProjectionMatrix;
	mat3 uNormalMatrix;
} Matrices;

layout( std140, set = 1, binding = 0 ) uniform lightBuf
{
	float uKa, uKd, uKs, uShininess;
	vec4 uLightPos;
	vec4 uLightSpecularColor;
	vec4 uEyePos; ;
} Light;

layout( std140, set = 2, binding = 0 ) uniform miscBuf
{
	float uTime;
	int   uMode;
	int   uLighting;
} Misc;

layout( set = 3, binding = 0 ) uniform sampler2D uSampler;
```

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Step 1: Descriptor Set Pools

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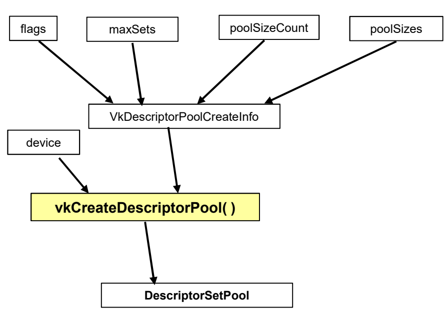
You don't allocate Descriptor Sets on the fly – that is too slow. Instead, you allocate a "pool" of Descriptor Sets and then pull from that pool later.



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```
VkResult
Init13DescriptorSetPool( )
{
	VkResult result;

	VkDescriptorPoolSize			vdps[4];
		vdps[0].type = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
		vdps[0].descriptorCount = 1;
		vdps[1].type = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
		vdps[1].descriptorCount = 1;
		vdps[2].type = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
		vdps[2].descriptorCount = 1;
		vdps[3].type = VK_DESCRIPTOR_TYPE_COMBINED_IMAGE_SAMPLER;
		vdps[3].descriptorCount = 1;

#ifdef CHOICES
VK_DESCRIPTOR_TYPE_SAMPLER
VK_DESCRIPTOR_TYPE_SAMPLED_IMAGE
VK_DESCRIPTOR_TYPE_COMBINED_IMAGE_SAMPLER
VK_DESCRIPTOR_TYPE_STORAGE_IMAGE
VK_DESCRIPTOR_TYPE_UNIFORM_TEXEL_BUFFER
VK_DESCRIPTOR_TYPE_STORAGE_TEXEL_BUFFER
VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER
VK_DESCRIPTOR_TYPE_STORAGE_BUFFER
VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER_DYNAMIC
VK_DESCRIPTOR_TYPE_STORAGE_BUFFER_DYNAMIC
VK_DESCRIPTOR_TYPE_INPUT_ATTACHMENT
#endif

	VkDescriptorPoolCreateInfo			vdpci;
		vdpci.sType = VK_STRUCTURE_TYPE_DESCRIPTOR_POOL_CREATE_INFO;
		vdpci.pNext = nullptr;
		vdpci.flags = 0;
		vdpci.maxSets = 4;
		vdpci.poolSizeCount = 4;
		vdpci.pPoolSizes = &vdps[0];

	result = vkCreateDescriptorPool( LogicalDevice, IN &vdpci, PALLOCATOR, OUT &DescriptorPool);
	return result;
}
```

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Step 2: Define the Descriptor Set Layouts

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I think of Descriptor Set Layouts as a kind of "Rosetta Stone" that allows the Graphics Pipeline data structure to allocate room for the uniform variables and to access them.

https://discoveringegypt.com

```
layout( std140, set = 0, binding = 0 ) uniform matBuf
{
	mat4 uModelMatrix;
	mat4 uViewMatrix;
	mat4 uProjectionMatrix;
	mat3 uNormalMatrix;
} Matrices;

layout( std140, set = 1, binding = 0 ) uniform lightBuf
{
	float uKa, uKd, uKs, uShininess;
	vec4 uLightPos;
	vec4 uLightSpecularColor;
	vec4 uEyePos; ;
} Light;

layout( std140, set = 2, binding = 0 ) uniform miscBuf
{
	float uTime;
	int   uMode;
	int   uLighting;
} Misc;

layout( set = 3, binding = 0 ) uniform sampler2D uSampler;
```

MatrixSet DS Layout Binding:	LightSet DS Layout Binding:	MiscSet DS Layout Binding:	TexSamplerSet DS Layout Binding:
binding descriptorType descriptorCount pipeline stage(s)	binding descriptorType descriptorCount pipeline stage(s)	binding descriptorType descriptorCount pipeline stage(s)	binding descriptorType descriptorCount pipeline stage(s)

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```
VkResult
Init13DescriptorSetLayouts( )
{
    VkResult result;

    //DS #0:
    VkDescriptorSetLayoutBinding         MatrixSet[1];
        MatrixSet[0].binding            = 0;
        MatrixSet[0].descriptorType     = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
        MatrixSet[0].descriptorCount    = 1;
        MatrixSet[0].stageFlags         = VK_SHADER_STAGE_VERTEX_BIT;
        MatrixSet[0].pImmutableSamplers = (VkSampler *)nullptr;

    // DS #1:
    VkDescriptorSetLayoutBinding         LightSet[1];
        LightSet[0].binding            = 0;
        LightSet[0].descriptorType     = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
        LightSet[0].descriptorCount    = 1;
        LightSet[0].stageFlags         = VK_SHADER_STAGE_VERTEX_BIT | VK_SHADER_STAGE_FRAGMENT_BIT;
        LightSet[0].pImmutableSamplers = (VkSampler *)nullptr;

    //DS #2:
    VkDescriptorSetLayoutBinding         MiscSet[1];
        MiscSet[0].binding            = 0;
        MiscSet[0].descriptorType     = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
        MiscSet[0].descriptorCount    = 1;
        MiscSet[0].stageFlags         = VK_SHADER_STAGE_VERTEX_BIT | VK_SHADER_STAGE_FRAGMENT_BIT;
        MiscSet[0].pImmutableSamplers = (VkSampler *)nullptr;

    // DS #3:
    VkDescriptorSetLayoutBinding         TexSamplerSet[1];
        TexSamplerSet[0].binding            = 0;
        TexSamplerSet[0].descriptorType     = VK_DESCRIPTOR_TYPE_COMBINED_IMAGE_SAMPLER;
        TexSamplerSet[0].descriptorCount    = 1;
        TexSamplerSet[0].stageFlags         = VK_SHADER_STAGE_FRAGMENT_BIT;
        TexSamplerSet[0].pImmutableSamplers = (VkSampler *)nullptr;
```

```
uniform sampler2D   uSampler;
vec4 rgba = texture( uSampler, vST );
```

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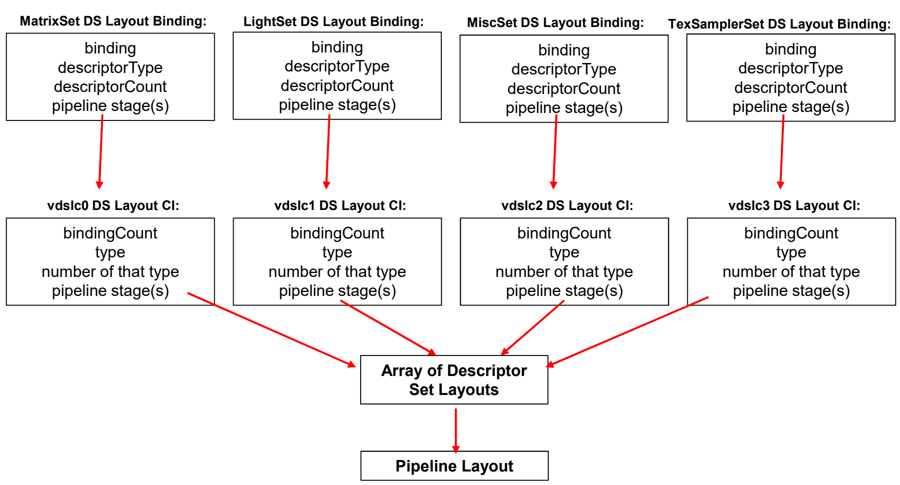
Step 2: Define the Descriptor Set Layouts



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```
VkDescriptorSetLayoutCreateInfo             vdslc0;
      vdslc0.sType = VK_STRUCTURE_TYPE_DESCRIPTOR_SET_LAYOUT_CREATE_INFO;
      vdslc0.pNext = nullptr;
      vdslc0.flags = 0;
      vdslc0.bindingCount = 1;
      vdslc0.pBindings = &MatrixSet[0];

VkDescriptorSetLayoutCreateInfo             vdslc1;
      vdslc1.sType = VK_STRUCTURE_TYPE_DESCRIPTOR_SET_LAYOUT_CREATE_INFO;
      vdslc1.pNext = nullptr;
      vdslc1.flags = 0;
      vdslc1.bindingCount = 1;
      vdslc1.pBindings = &LightSet[0];

VkDescriptorSetLayoutCreateInfo             vdslc2;
      vdslc2.sType = VK_STRUCTURE_TYPE_DESCRIPTOR_SET_LAYOUT_CREATE_INFO;
      vdslc2.pNext = nullptr;
      vdslc2.flags = 0;
      vdslc2.bindingCount = 1;
      vdslc2.pBindings = &MiscSet[0];

VkDescriptorSetLayoutCreateInfo             vdslc3;
      vdslc3.sType = VK_STRUCTURE_TYPE_DESCRIPTOR_SET_LAYOUT_CREATE_INFO;
      vdslc3.pNext = nullptr;
      vdslc3.flags = 0;
      vdslc3.bindingCount = 1;
      vdslc3.pBindings = &TexSamplerSet[0];

result = vkCreateDescriptorSetLayout( LogicalDevice, &vdslc0, PALLOCATOR, OUT &DescriptorSetLayouts[0] );
result = vkCreateDescriptorSetLayout( LogicalDevice, &vdslc1, PALLOCATOR, OUT &DescriptorSetLayouts[1] );
result = vkCreateDescriptorSetLayout( LogicalDevice, &vdslc2, PALLOCATOR, OUT &DescriptorSetLayouts[2] );
result = vkCreateDescriptorSetLayout( LogicalDevice, &vdslc3, PALLOCATOR, OUT &DescriptorSetLayouts[3] );

return result;
}
```

Array of Descriptor Set Layouts

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Step 3: Include the Descriptor Set Layouts in a Graphics Pipeline Layout

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```
VkResult
Init14GraphicsPipelineLayout( )
{
      VkResult result;

      VkPipelineLayoutCreateInfo             vplci;
            vplci.sType = VK_STRUCTURE_TYPE_PIPELINE_LAYOUT_CREATE_INFO;
            vplci.pNext = nullptr;
            vplci.flags = 0;
            vplci.setLayoutCount = 4;
            vplci.pSetLayouts = &DescriptorSetLayouts[0];
            vplci.pushConstantRangeCount = 0;
            vplci.pPushConstantRanges = (VkPushConstantRange *)nullptr;

      result = vkCreatePipelineLayout( LogicalDevice, IN &vplci, PALLOCATOR, OUT &GraphicsPipelineLayout );

      return result;
}
```

Array of Descriptor Set Layouts

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Step 4: Allocating the Memory for Descriptor Sets

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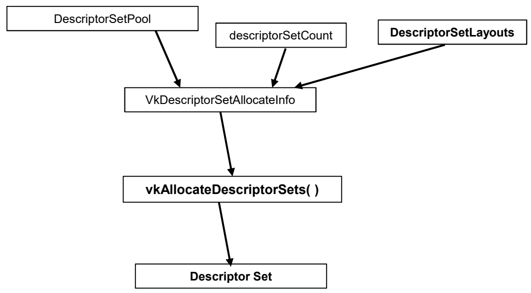

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Step 4: Allocating the Memory for Descriptor Sets

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```
VkResult
Init13DescriptorSets( )
{
	VkResult result;

	VkDescriptorSetAllocateInfo			+;
		vdsai.sType = VK_STRUCTURE_TYPE_DESCRIPTOR_SET_ALLOCATE_INFO;
		vdsai.pNext = nullptr;
		vdsai.descriptorPool = DescriptorPool;
		vdsai.descriptorSetCount = 4;
		vdsai.pSetLayouts = DescriptorSetLayouts;

	result = vkAllocateDescriptorSets( LogicalDevice, IN &vdsai, OUT &DescriptorSets[0] );
```

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Step 5: Tell the Descriptor Sets where their CPU Data is

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

VkDescriptorBufferInfo                vdbi1;
        vdbi1.buffer = MyLightUniformBuffer.buffer;
        vdbi1.offset = 0;
        vdbi1.range = sizeof(Light);

VkDescriptorBufferInfo                vdbi2;
        vdbi2.buffer = MyMiscUniformBuffer.buffer;
        vdbi2.offset = 0;
        vdbi2.range = sizeof(Misc);

VkDescriptorImageInfo                 vdii0;
        vdii.sampler   = MyPuppyTexture.texSampler;
        vdii.imageView = MyPuppyTexture.texImageView;
        vdii.imageLayout = VK_IMAGE_LAYOUT_SHADER_READ_ONLY_OPTIMAL;
```

This struct identifies what buffer it owns and how big it is

This struct identifies what buffer it owns and how big it is

This struct identifies what buffer it owns and how big it is

This struct identifies what texture sampler and image view it owns

Good to use ***sizeof***

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Step 5: Tell the Descriptor Sets where their CPU Data is

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```
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 = IN &vdbi0;
        vwds0.pImageInfo = (VkDescriptorImageInfo *)nullptr;
        vwds0.pTexelBufferView = (VkBufferView *)nullptr;

        // ds 1:
    VkWriteDescriptorSet                  vwds1;
        vwds1.sType = VK_STRUCTURE_TYPE_WRITE_DESCRIPTOR_SET;
        vwds1.pNext = nullptr;
        vwds1.dstSet = DescriptorSets[1];
        vwds1.dstBinding = 0;
        vwds1.dstArrayElement = 0;
        vwds1.descriptorCount = 1;
        vwds1.descriptorType = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
        vwds1.pBufferInfo = IN &vdbi1;
        vwds1.pImageInfo = (VkDescriptorImageInfo *)nullptr;
        vwds1.pTexelBufferView = (VkBufferView *)nullptr;
```

This struct links a Descriptor Set to the buffer it is pointing tto

This struct links a Descriptor Set to the buffer it is pointing tto

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Step 5: Tell the Descriptor Sets where their data is

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```
VkWriteDescriptorSet                    vwds2;
        // ds 2:
        vwds2.sType = VK_STRUCTURE_TYPE_WRITE_DESCRIPTOR_SET;
        vwds2.pNext = nullptr;
        vwds2.dstSet = DescriptorSets[2];
        vwds2.dstBinding = 0;
        vwds2.dstArrayElement = 0;
        vwds2.descriptorCount = 1;
        vwds2.descriptorType = VK_DESCRIPTOR_TYPE_UNIFORM_BUFFER;
        vwds2.pBufferInfo = IN &vdbi2;
        vwds2.pImageInfo = (VkDescriptorImageInfo *)nullptr;
        vwds2.pTexelBufferView = (VkBufferView *)nullptr;

        // ds 3:
VkWriteDescriptorSet                    vwds3;
        vwds3.sType = VK_STRUCTURE_TYPE_WRITE_DESCRIPTOR_SET;
        vwds3.pNext = nullptr;
        vwds3.dstSet = DescriptorSets[3];
        vwds3.dstBinding = 0;
        vwds3.dstArrayElement = 0;
        vwds3.descriptorCount = 1;
        vwds3.descriptorType = VK_DESCRIPTOR_TYPE_COMBINED_IMAGE_SAMPLER;
        vwds3.pBufferInfo = (VkDescriptorBufferInfo *)nullptr;
        vwds3.pImageInfo = IN &vdii0;
        vwds3.pTexelBufferView = (VkBufferView *)nullptr;

uint32_t copyCount = 0;

// this could have been done with one call and an array of VkWriteDescriptorSets:

vkUpdateDescriptorSets( LogicalDevice, 1, IN &vwds0, IN copyCount, (VkCopyDescriptorSet *)nullptr );
vkUpdateDescriptorSets( LogicalDevice, 1, IN &vwds1, IN copyCount, (VkCopyDescriptorSet *)nullptr );
vkUpdateDescriptorSets( LogicalDevice, 1, IN &vwds2, IN copyCount, (VkCopyDescriptorSet *)nullptr );
vkUpdateDescriptorSets( LogicalDevice, 1, IN &vwds3, IN copyCount, (VkCopyDescriptorSet *)nullptr );
```

This struct links a Descriptor Set to the buffer it is pointing tto

This struct links a Descriptor Set to the image it is pointing to

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Step 6: Include the Descriptor Set Layout when Creating a Graphics Pipeline

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```
VkGraphicsPipelineCreateInfo                    vgpci;
        vgpci.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
        vgpci.pNext = nullptr;
        vgpci.flags = 0;
#ifdef CHOICES
VK_PIPELINE_CREATE_DISABLE_OPTIMIZATION_BIT
VK_PIPELINE_CREATE_ALLOW_DERIVATIVES_BIT
VK_PIPELINE_CREATE_DERIVATIVE_BIT
#endif
        vgpci.stageCount = 2;       // number of stages in this pipeline = vertex + fragment
        vgpci.pStages = vpssci;
        vgpci.pVertexInputState = &vpvisci;
        vgpci.pInputAssemblyState = &vpiasci;
        vgpci.pTessellationState = (VkPipelineTessellationStateCreateInfo *)nullptr;
        vgpci.pViewportState = &vpvsci;
        vgpci.pRasterizationState = &vprsci;
        vgpci.pMultisampleState = &vpmsci;
        vgpci.pDepthStencilState = &vpdssci;
        vgpci.pColorBlendState = &vpcbsci;
        vgpci.pDynamicState = &vpdsci;
        vgpci.layout = IN GraphicsPipelineLayout;
        vgpci.renderPass = IN RenderPass;
        vgpci.subpass = 0;                  // subpass number
        vgpci.basePipelineHandle = (VkPipeline) VK_NULL_HANDLE;
        vgpci.basePipelineIndex = 0;

    result = vkCreateGraphicsPipelines( LogicalDevice, VK_NULL_HANDLE, 1, IN &vgpci,
                                        PALLOCATOR, OUT &GraphicsPipeline );
```

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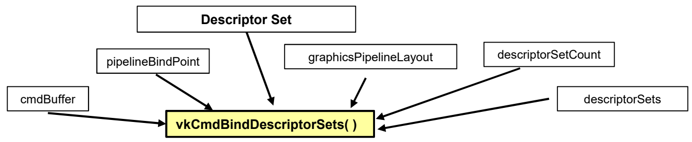
Step 7: Bind Descriptor Sets into the Command Buffer when Drawing




```
vkCmdBindDescriptorSets( CommandBuffers[nextImageIndex],
                    VK_PIPELINE_BIND_POINT_GRAPHICS, GraphicsPipelineLayout,
                    0, 4, DescriptorSets, 0, (uint32_t *)nullptr );
```