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Antialiasing and Multisampling

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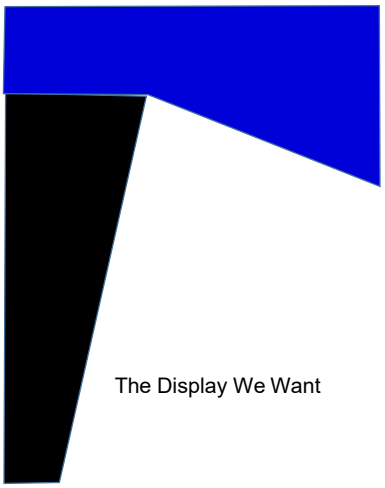
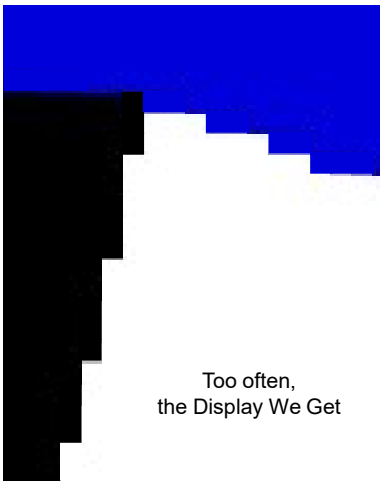
Aliasing



The Display We Want



Too often,
the Display We Get

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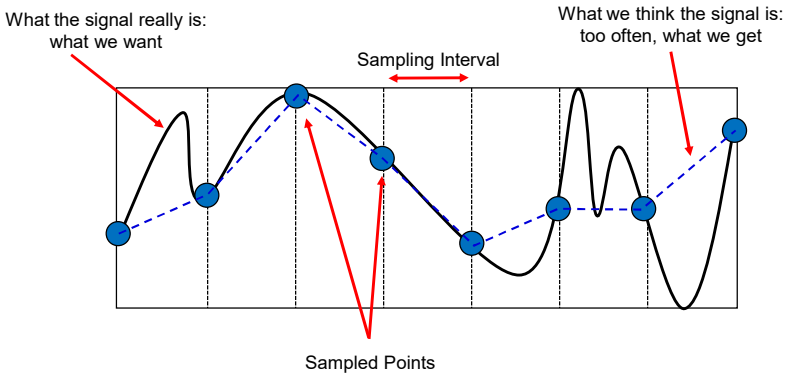
Aliasing

"Aliasing" is a signal-processing term for "under-sampled compared with the frequencies in the signal".



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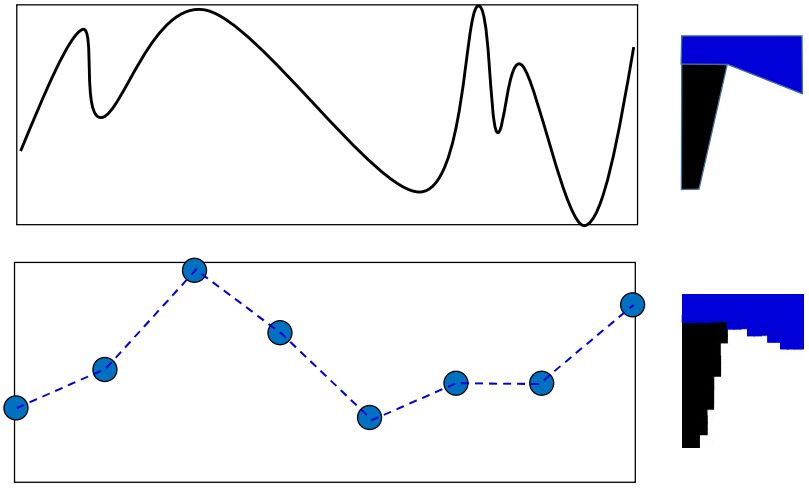
Aliasing



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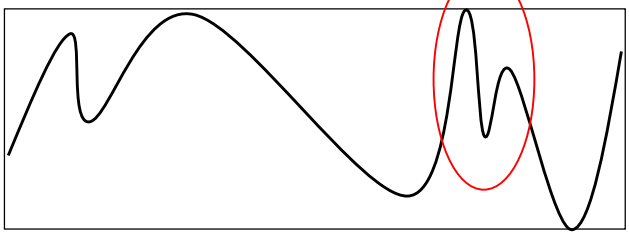
The Nyquist Criterion

"The Nyquist [sampling] rate is twice the maximum component frequency of the function [i.e., signal] being sampled." -- WikiPedia



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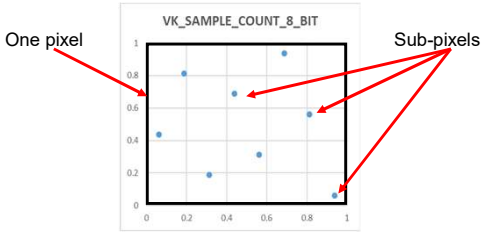
MultiSampling

Oversampling is a computer graphics technique to improve the quality of your output image by looking inside every pixel to see what the rendering is doing there.

There are two approaches to this:

1. **Supersampling**: Pick some number of sub-pixels within that pixel that pass the depth and stencil tests. Render the image at each of these sub-pixels..



2. **Multisampling**: Pick some number of sub-pixels within that pixel that pass the depth and stencil tests. If any of them pass, then perform a single color render for the one pixel and assign that single color to all the sub-pixels that passed the depth and stencil tests.

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The final step will be to average those sub-pixels' colors to produce one final color for this whole pixel. This is called ***resolving*** the pixel.

Vulkan Specification Distribution of Sampling Points within a Pixel

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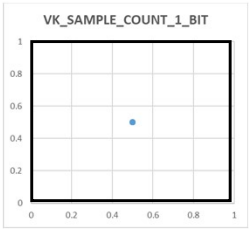

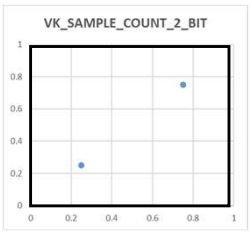

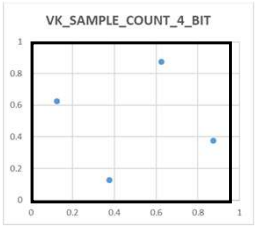

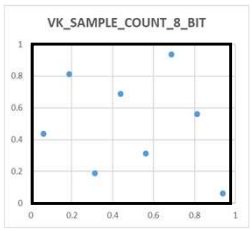

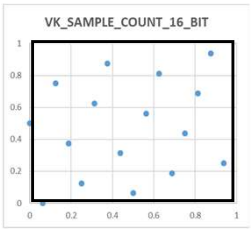

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Vulkan Specification Distribution of Sampling Points within a Pixel

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VK_SAMPLE_COUNT_2_BIT	VK_SAMPLE_COUNT_4_BIT	VK_SAMPLE_COUNT_8_BIT	VK_SAMPLE_COUNT_16_BIT
		(0.5625, 0.3125)	(0.5625, 0.5625)
	(0.375, 0.125)		(0.4375, 0.3125)
		(0.4375, 0.6875)	(0.3125, 0.625)
			(0.75, 0.4375)
(0.25,0.25)		(0.8125, 0.5625)	(0.1875, 0.375)
	(0.875, 0.375)		(0.625, 0.8125)
		(0.3125, 0.1875)	(0.8125, 0.6875)
			(0.6875, 0.1875)
		(0.1875, 0.8125)	(0.375, 0.875)
	(0.125, 0.625)		(0.5, 0.0625)
		(0.0625, 0.4375)	(0.25, 0.125)
(0.75,0.75)			(0.125, 0.75)
		(0.6875, 0.9375)	(0.0, 0.5)
	(0.625, 0.875)		(0.9375, 0.25)
		(0.9375, 0.0625)	(0.875, 0.9375)
			(0.0625, 0.0)

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Consider Two Triangles That Pass Through the Same Pixel

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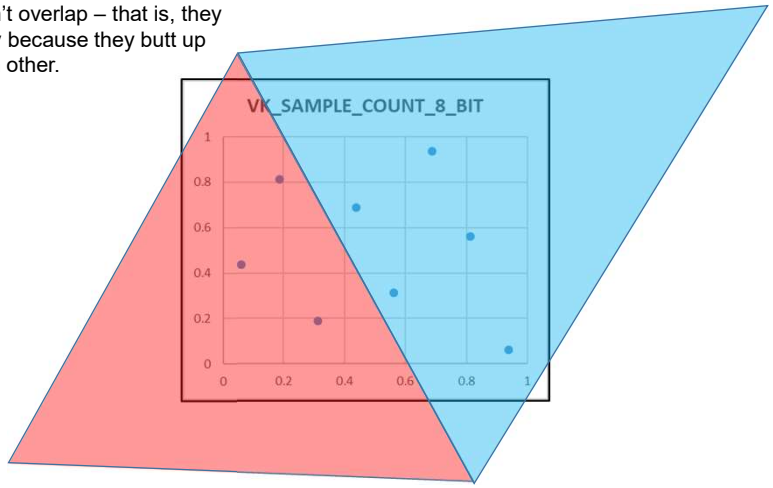
Let's assume (for now) that the two triangles don't overlap – that is, they look this way because they butt up against each other.



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Supersampling

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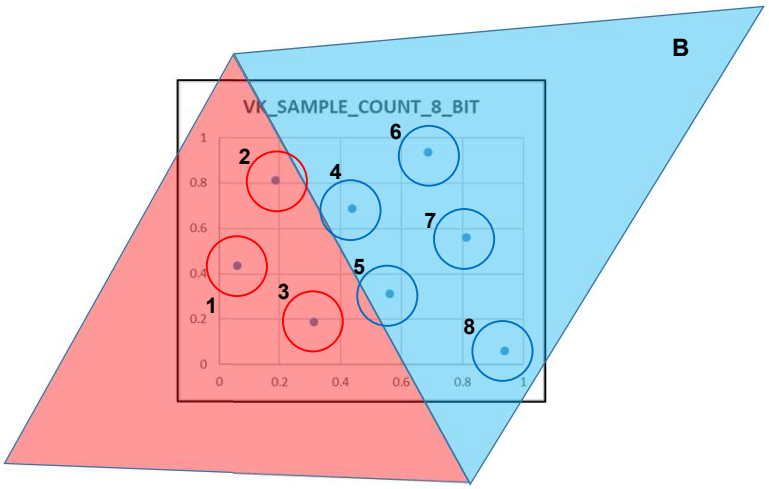

$$Final\ Pixel\ Color = \frac{\sum_{i=1}^{8} Color\ sample\ from\ subpixel_i}{8}$$

 # Fragment Shader calls = 8

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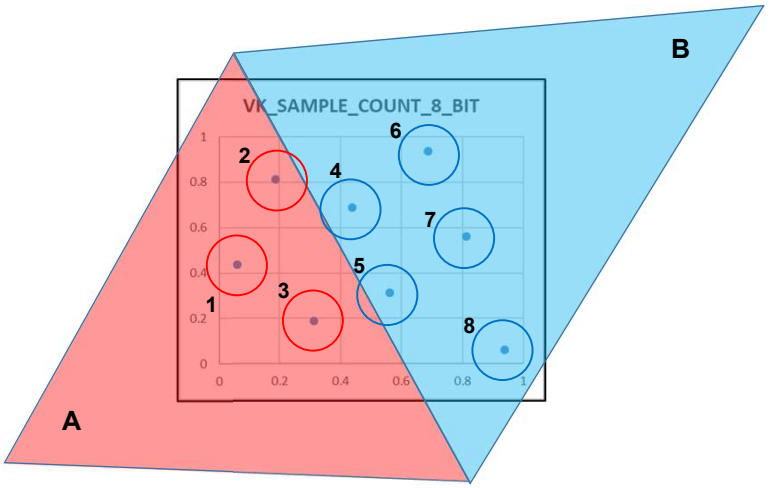
Multisampling

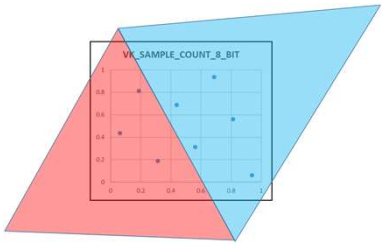


$$Final\ Pixel\ Color = \frac{3 * One\ color\ sample\ from\ A\ +\ 5 * One\ color\ sample\ from\ B}{8}$$

 # Fragment Shader calls = 2

Consider Two Triangles Who Pass Through the Same Pixel

Let's assume (for now) that the two triangles don't overlap – that is, they look this way because they butt up against each other.



Number of Fragment Shader Calls

	Multisampling	Supersampling
Blue fragment shader calls	1	5
Red fragment shader calls	1	3

Consider Two Triangles Who Pass Through the Same Pixel

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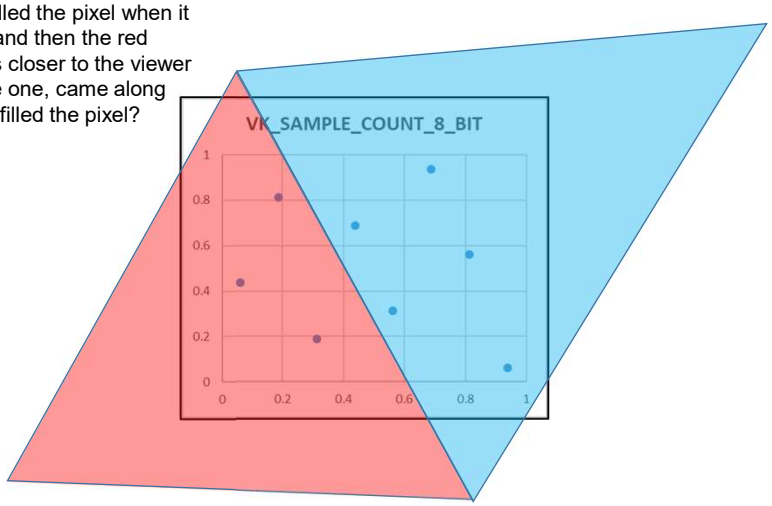
Q: What if the blue triangle completely filled the pixel when it was drawn, and then the red one, which is closer to the viewer than the blue one, came along and partially filled the pixel?



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A: The ideas are all still the same, but the blue one had to deal with 8 sub-pixels (instead of 5 like before). But, the red triangle came along and obsoleted 3 of those blue sub-pixels. Note that the "resolved" image will still turn out the same as before.

Consider Two Triangles Who Pass Through the Same Pixel

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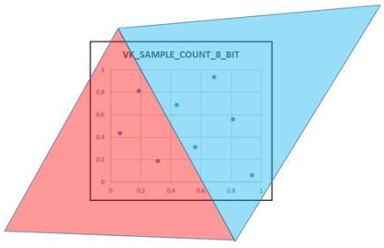
What if the blue triangle completely filled the pixel when it was drawn, and then the red one, which is closer to the viewer than the blue one, came along and partially filled the pixel?



Number of Fragment Shader Calls

	Multisampling	Supersampling
Blue fragment shader calls	1	8
Red fragment shader calls	1	3

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Setting up the Image


```
VkPipelineMultisampleStateCreateInfo        vpmsci;
        vpmsci.sType = VK_STRUCTURE_TYPE_PIPELINE_MULTISAMPLE_STATE_CREATE_INFO;
        vpmsci.pNext = nullptr;
        vpmsci.flags = 0;
        vpmsci.rasterizationSamples = VK_SAMPLE_COUNT_8_BIT;
        vpmsci.sampleShadingEnable = VK_TRUE;
        vpmsci.minSampleShading = 0.5f;
        vpmsci.pSampleMask = (VkSampleMask *)nullptr;
        vpmsci.alphaToCoverageEnable = VK_FALSE;
        vpmsci.alphaToOneEnable = VK_FALSE;

VkGraphicsPipelineCreateInfo                vgpci;
        vgpci.sType = VK_STRUCTURE_TYPE_GRAPHICS_PIPELINE_CREATE_INFO;
        vgpci.pNext = nullptr;
    . . .
        vgpci.pMultisampleState = &vpmsci;

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

How dense is the sampling

VK_TRUE means to allow some sort of multisampling to take place

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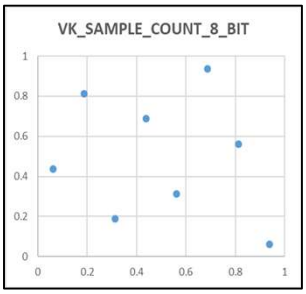
Setting up the Image


```
VkPipelineMultisampleStateCreateInfo        vpmsci;
        . . .
        vpmsci.minSampleShading = 0.5;
        . . .
```



At least this fraction of samples will get their own fragment shader calls (as long as they pass the depth and stencil tests).

0. produces simple multisampling

(0. - 1.) produces partial supersampling

1. Produces complete supersampling

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Setting up the Image

```
VkAttachmentDescription                 vad[2];
        vad[0].format = VK_FORMAT_B8G8R8A8_SRGB;
        vad[0].samples = VK_SAMPLE_COUNT_8_BIT;
        vad[0].loadOp = VK_ATTACHMENT_LOAD_OP_CLEAR;
        vad[0].storeOp = VK_ATTACHMENT_STORE_OP_STORE;
        vad[0].stencilLoadOp = VK_ATTACHMENT_LOAD_OP_DONT_CARE;
        vad[0].stencilStoreOp = VK_ATTACHMENT_STORE_OP_DONT_CARE;
        vad[0].initialLayout = VK_IMAGE_LAYOUT_UNDEFINED;
        vad[0].finalLayout = VK_IMAGE_LAYOUT_PRESENT_SRC_KHR;
        vad[0].flags = 0;

        vad[1].format = VK_FORMAT_D32_SFLOAT_S8_UINT;
        vad[1].samples = VK_SAMPLE_COUNT_8_BIT;
        vad[1].loadOp = VK_ATTACHMENT_LOAD_OP_CLEAR;
        vad[1].storeOp = VK_ATTACHMENT_STORE_OP_DONT_CARE;
        vad[1].stencilLoadOp = VK_ATTACHMENT_LOAD_OP_DONT_CARE;
        vad[1].stencilStoreOp = VK_ATTACHMENT_STORE_OP_DONT_CARE;
        vad[1].initialLayout = VK_IMAGE_LAYOUT_UNDEFINED;
        vad[1].finalLayout = VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL;
        vad[1].flags = 0;

VkAttachmentReference                   colorReference;
        colorReference.attachment = 0;
        colorReference.layout = VK_IMAGE_LAYOUT_COLOR_ATTACHMENT_OPTIMAL;

VkAttachmentReference                   depthReference;
        depthReference.attachment = 1;
        depthReference.layout = VK_IMAGE_LAYOUT_DEPTH_STENCIL_ATTACHMENT_OPTIMAL;
```

to next slide

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Setting up the Image

```
VkSubpassDescription                    vsd;
        vsd.flags = 0;
        vsd.pipelineBindPoint = VK_PIPELINE_BIND_POINT_GRAPHICS;
        vsd.inputAttachmentCount = 0;
        vsd.pInputAttachments = (VkAttachmentReference *)nullptr;
        vsd.colorAttachmentCount = 1;
        vsd.pColorAttachments = &colorReference;
        vsd.pResolveAttachments = (VkAttachmentReference *)nullptr;
        vsd.pDepthStencilAttachment = &depthReference;
        vsd.preserveAttachmentCount = 0;
        vsd.pPreserveAttachments = (uint32_t *)nullptr;

VkRenderPassCreateInfo                  vrpci;
        vrpci.sType = VK_STRUCTURE_TYPE_RENDER_PASS_CREATE_INFO;
        vrpci.pNext = nullptr;
        vrpci.flags = 0;
        vrpci.attachmentCount = 2;              // color and depth/stencil
        vrpci.pAttachments = vad;
        vrpci.subpassCount = 1;
        vrpci.pSubpasses = IN &vsd;
        vrpci.dependencyCount = 0;
        vrpci.pDependencies = (VkSubpassDependency *)nullptr;


result = vkCreateRenderPass( LogicalDevice, IN &vrpci, PALLOCATOR, OUT &RenderPass );
```

from previous slide

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Resolving the Image:
Converting the Multisampled Image to a VK_SAMPLE_COUNT_1_BIT image


```
VlOffset3D                                  vo3;
        vo3.x = 0;
        vo3.y = 0;
        vo3.z = 0;

VkExtent3D                                  ve3;
        ve3.width = Width;
        ve3.height = Height;
        ve3.depth = 1;

VkImageSubresourceLayers                    visl;
        visl.aspectMask = VK_IMAGE_ASPECT_COLOR_BIT;
        visl.mipLevel = 0;
        visl.baseArrayLayer = 0;
        visl.layerCount = 1;

VkImageResolve                              vir;
        vir.srcSubresource = visl;
        vir.srcOffset = vo3;
        vir.dstSubresource = visl;
        vir.dstOffset = vo3;
        vir.extent = ve3;

vkCmdResolveImage( cmdBuffer, srcImage, srcImageLayout,  dstImage, dstImageLayout, 1, IN &vir );
```

For the *ImageLayout, use VK_IMAGE_LAYOUT_GENERAL