White Paper

Subject:	Internal True Colour
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Copyright:	
File Name:	Internal True ColourWhite Paper.doc
Issue Number:	1.0.6
Issue Date:	07 Dec 00

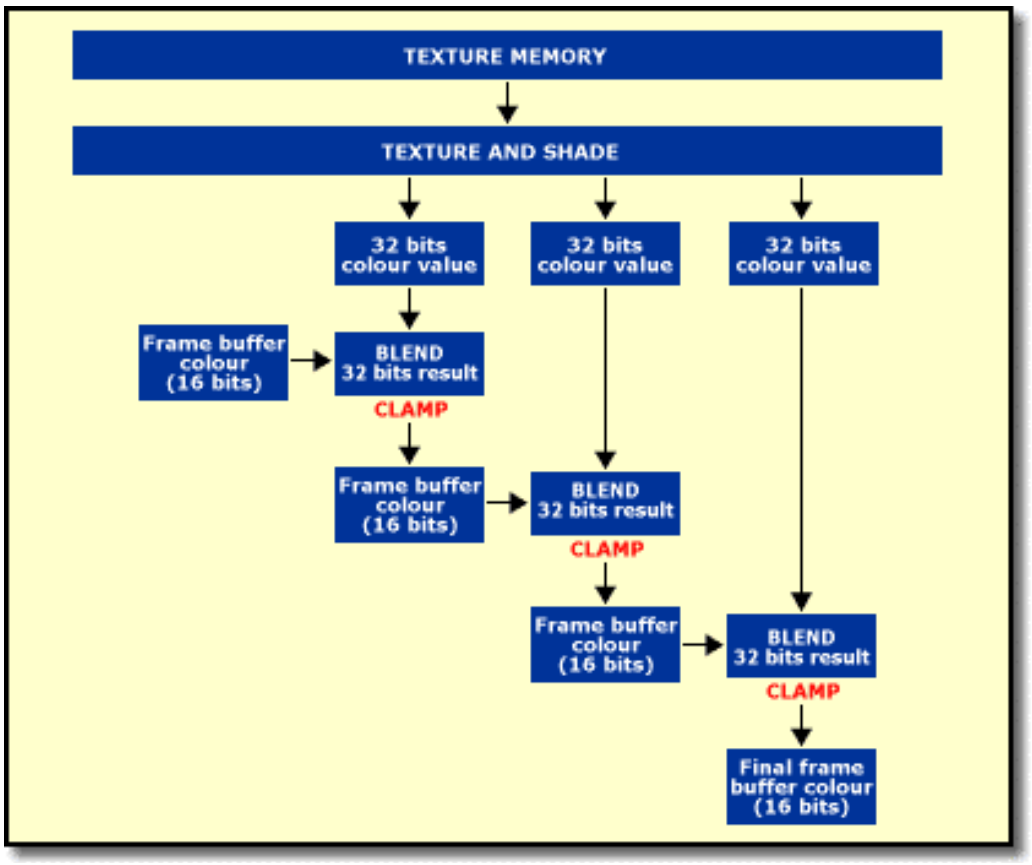
Introduction

Did you ever wonder why people say that you have to run Quake 3 in 32-bit mode? They argue the image quality is not good enough in 16-bit mode. Games today are getting more demanding on the graphics, but do you really have to reduce your performance and use 32-bit mode to get the quality? Not with PowerVR. When performing multiple blending operations in a 3D scene, the colour precision of the resulting blended pixels are a direct factor of the Frame Buffer bit depth. On traditional 16-bits Frame Buffers, it is common to observe "banding" due to the accumulated errors when blending pixels together. While dithering is commonly used to solve these effects, it can also give an undesirable "grainy" look to the scene. This document shows how PowerVR overcomes these effects.

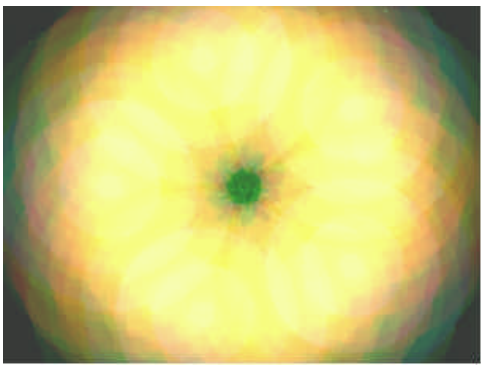
Traditional Hardware

Because traditional 3D systems are immediate mode and render polygons in the order that they are sent, each polygon has to be written out to memory upon completion. If subsequent polygons are blended on those already rendered e.g. to create an explosion effect, the previous ones must be read back into the chip, blended, and the result written back to memory. Apart from consuming memory bandwidth, this can also lead to serious image quality degradation when rendering in 16bpp modes as each polygon is rendered internally at 32bpp, dithered to 16bpp when written to the frame buffer and then read back in for use in further blend operations leading to cumulative image degradation as though a video tape copy has been used to make further copies. This loss of accuracy becomes quite noticeable when a number of blending operations are performed.

The following figure shows three blending operations on traditional hardware in 16-bit mode.



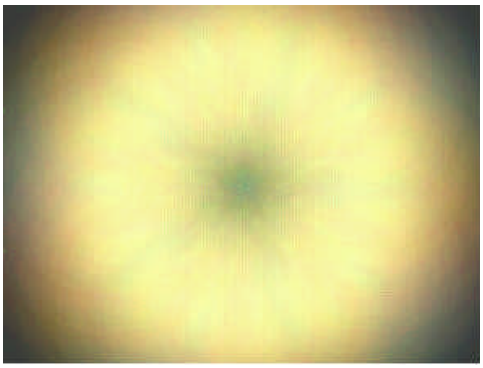
This results in visual artefacts:



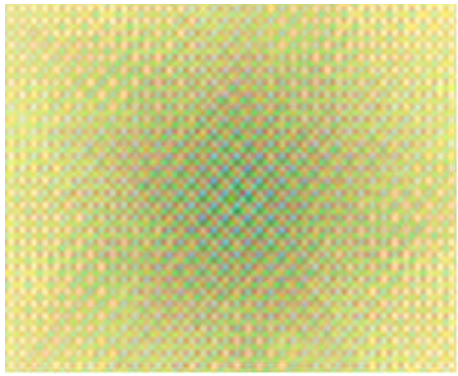
Blending to 16bpp

Blending to 32bpp

Dithering is typically used to make the visual errors less noticeable. Dithering approximates a colour by using a number of the other colours available and distributing the error across them. Dithering tends to reduce the obvious errors caused by colour truncation but results in a grainier image and is also much less effective when the dithering process is repeated, as it must be when pixels written out are used again in a blend operation.



Blending to 16bpp with dithering



Zoomed in dither pattern

Finally, traditional 3D renderers must use a 32bpp frame buffer to achieve certain blending effects which use the Alpha (or translucency) component of triangles already rendered to screen. This is because the Alpha component is lost in the conversion from 32bpp to 16bpp.

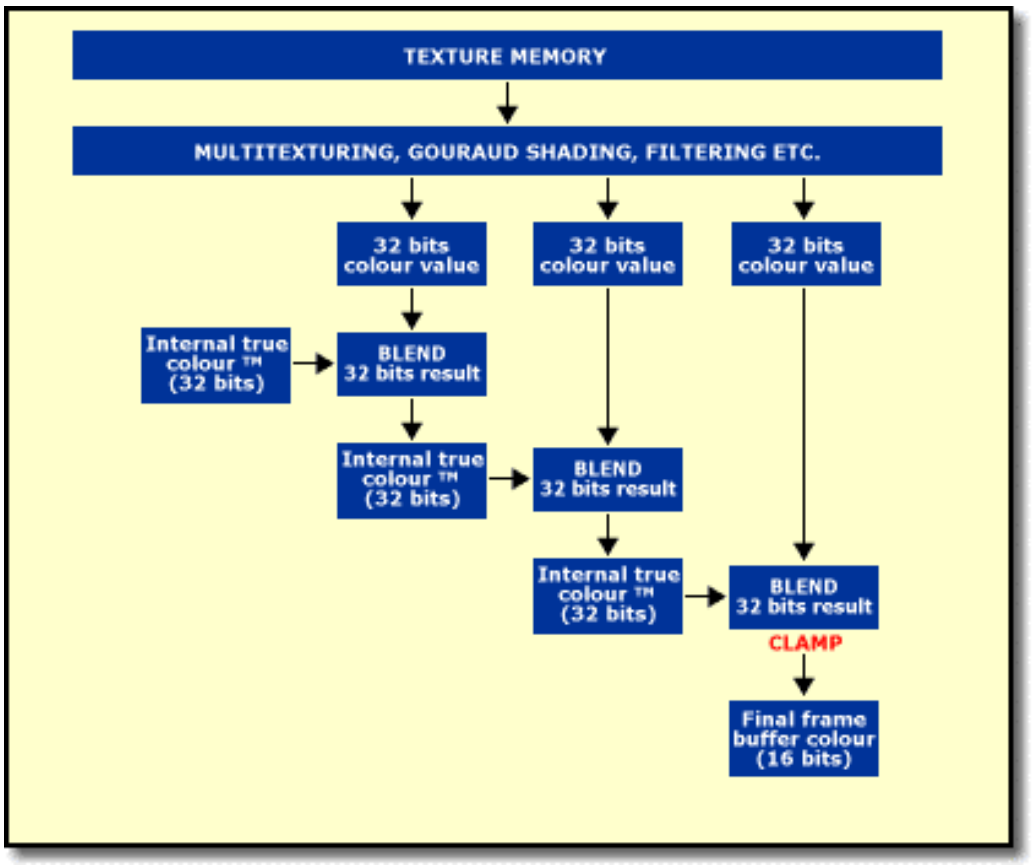
PowerVR Hardware

PowerVR is a "display list renderer", that is, groups of polygons are batched together (into a display list) before being processed by the 3D rendering hardware. This is fundamentally different to the approach used by conventional systems, since it allows a scene to be partitioned into small "tiles" or "regions" each of which is rendered independently, leading to the key benefits of improved price performance, scalability and image quality.

Since z-buffering and pixel blending are done entirely on-chip they can be performed at higher precision with no performance degradation. In PowerVR all pixel blend operations are performed with true colour precision, irrespective of the number of translucent layers or the bit-depth of the frame buffer resulting in high image quality without performance loss.

PowerVR's Internal True Colour™ performs all blending operations on all the pixels in each tile at the full 32bpp colour resolution before performing a single high quality error diffusion dither to 16bpp on output to the frame buffer if necessary. In fact, PowerVR's quality of rendering at 16bpp is the equal or better of many systems quality at 32bpp.

PowerVR Frame Buffer Access - Figure 2 shows a three layers blending process on a PowerVR 16-bits Frame Buffer.



On PowerVR's Internal True Colour™ no precision is lost during the blending process. Only the final colour to be output to the Frame Buffer is truncated to a 16-bits value. This results in an image quality far superior than common 16-bits Frame Buffer renderers:

Internal True Colour™ Dithering - 16 bit

Internal True Colour™ 16-bit Dithering x4

Summary

PowerVR's Internal True Colour™ boasts superior image quality compared to other traditional hardware. In 16 bits mode, PowerVR avoids the colour banding or grainy effects present on other hardware allowing you to maintain the 16bpp performance in the game without sacrificing visual quality. Because Internal True Colour™ blending also saves memory bandwidth (avoiding the multiple read/write frame buffer operations that traditional renderers have to perform) whatever the colour depth, PowerVR provides class-leading performance in 32bpp modes as well.