GLINT Gamma

A 3D Geometry and Lighting Processor for the PC

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Agenda

- A backgrounder to the 3D geometry pipeline
- System considerations for 3D geometry acceleration
- GLINT Gamma architecture overview
- GLINT Gamma detailed architecture
- Board design examples using GLINT Gamma

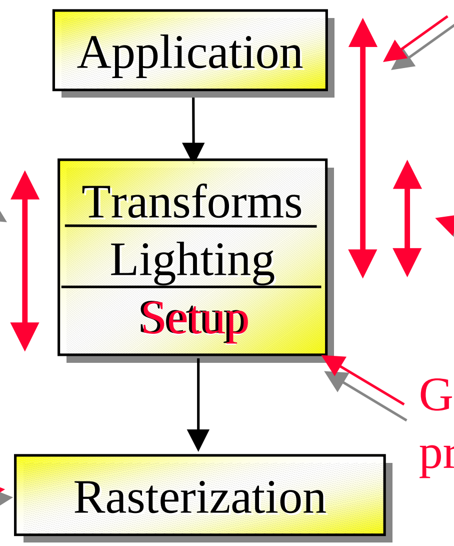
Geometry is the PC's 3D Bottleneck

The last difference between 3D workstations and PCs

- The fastest CPU *cannot* keep today's rasterization silicon saturated if running the geometry in software
- Professional 3D is particularly demanding
  - Many small polygons used for precise modeling of surfaces
  - Viewperf uses polygons less than 1 pixel in size

CPU running application & geometry = 350K polygons/sec

Complete geometry pipeline in software = 350K polygons/sec on a PII/266



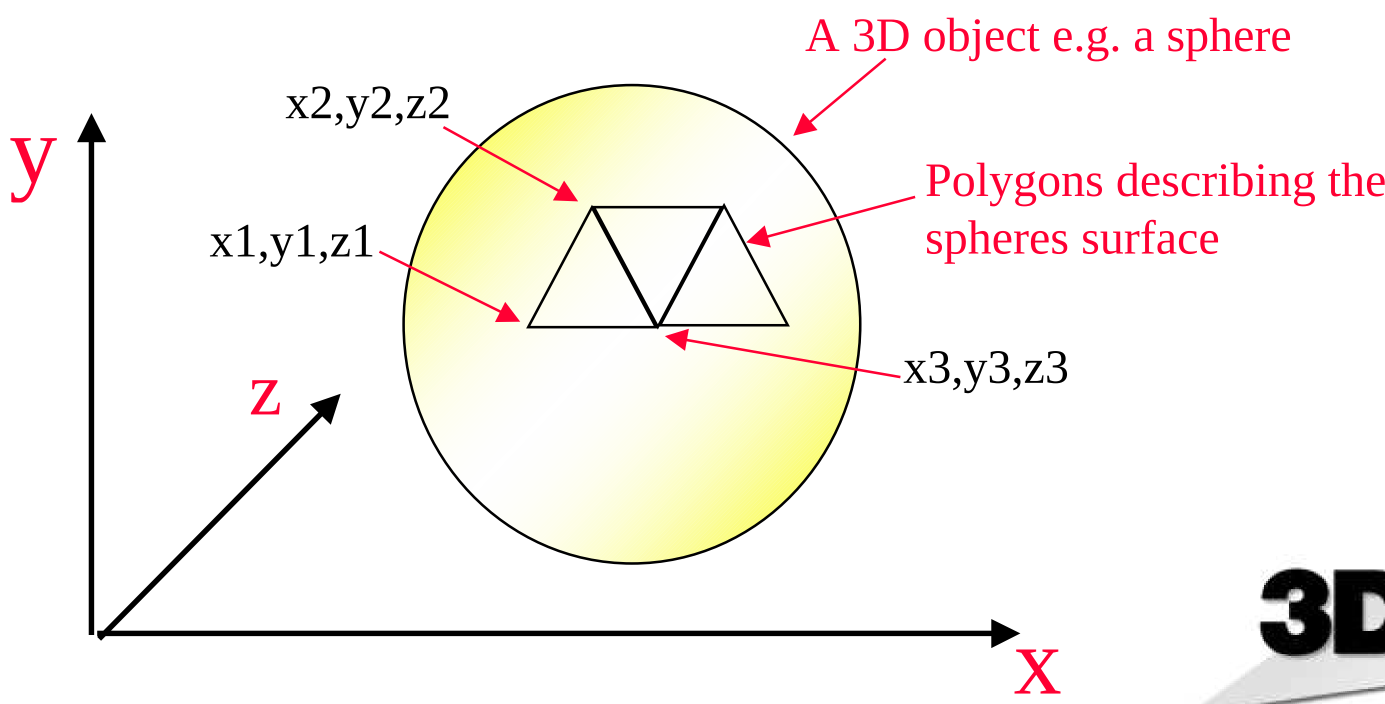
Transform and lighting in software = 1 million polygons/sec

GLINT Delta offloads setup processing = 100MFlops

100% of Rasterization in silicon - typically 500K-1M polygons per second

What *is* a 3D Object?

- Surfaces of objects are described as a grid of polygons
- The vertices of the polygons are located in 3D coordinate space - x,y,z
- The objects making up a scene are held in a database



3D Processing Stages

The journey from database to screen

Operations on Vertices

Geometry

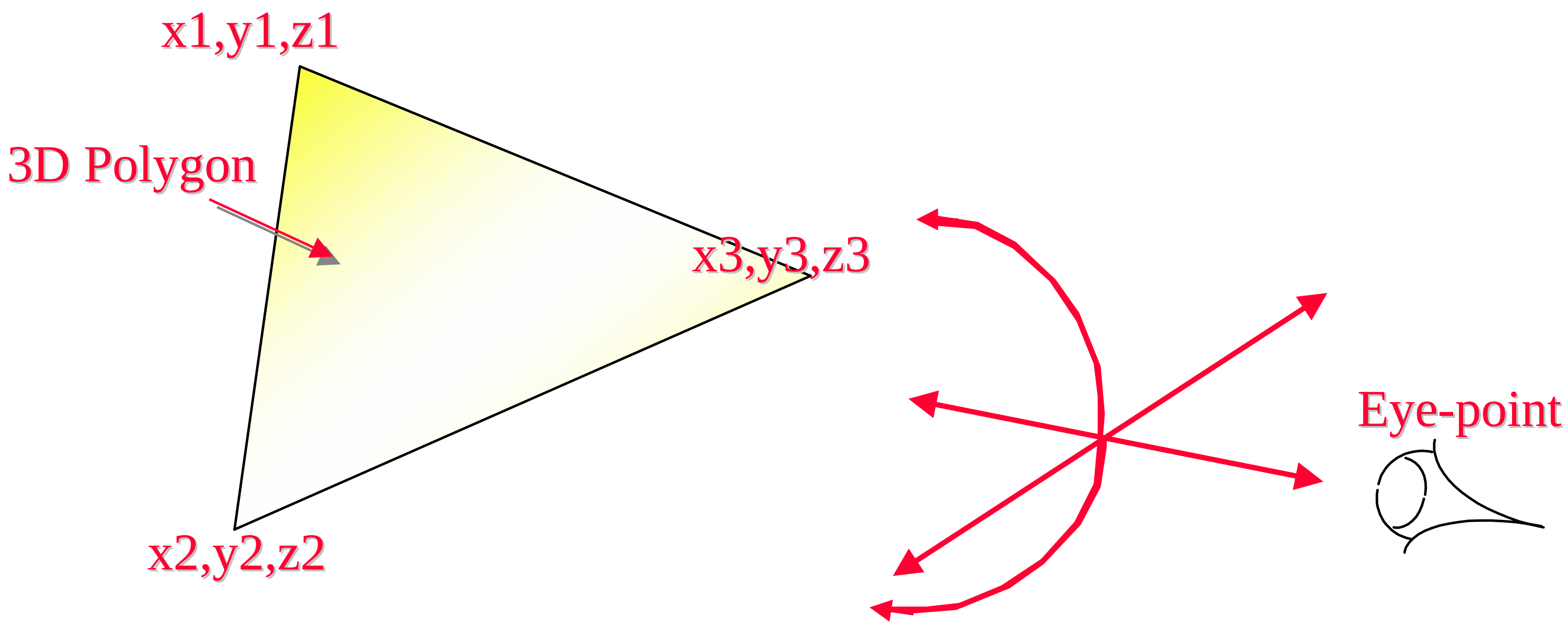
Stage	
Traversal	What objects are in current scene?
Transforms	Where are the polygons?
Lighting	What color are the polygons?
Setup	What shape are they on the screen?
Coverage	Which pixels are covered?
Color	What color is each pixel?
Clip	Which pixels are visible?
Merge	Write the pixels to the framebuffer

Rasterization

Operations on Pixels

Transform Processing

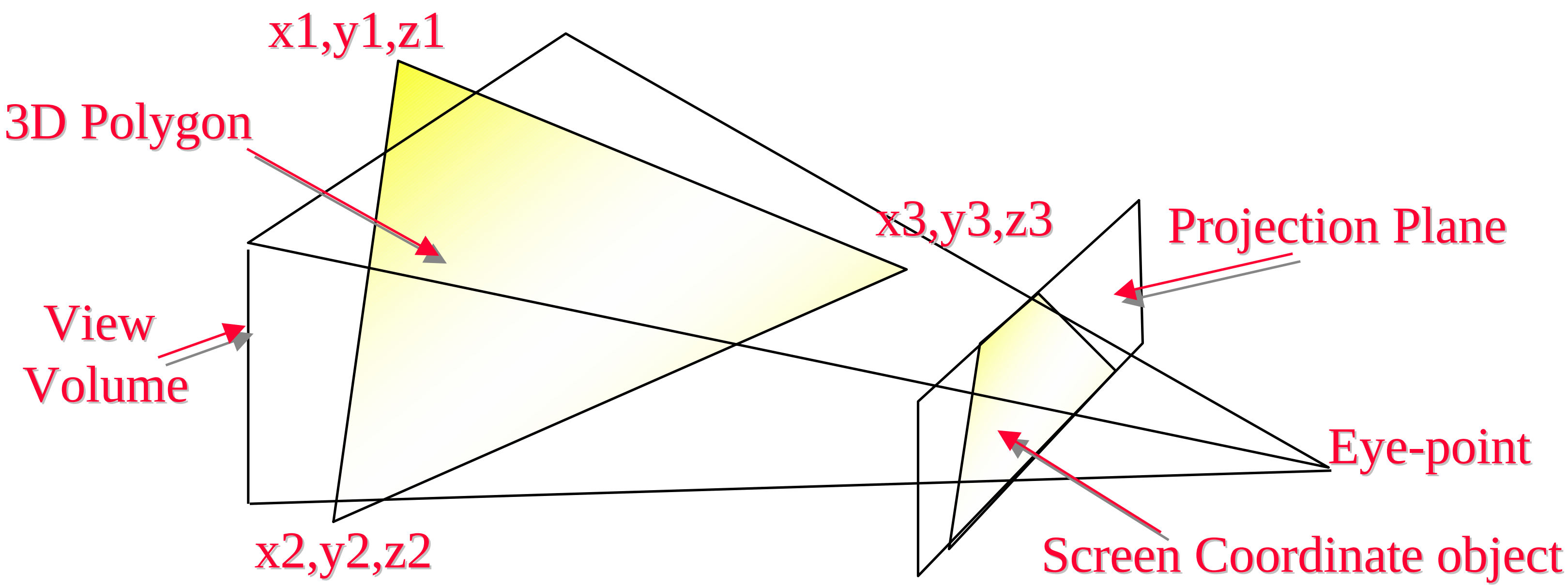
Positioning objects in a scene



- Input = the vertices of all objects in the scene in a database
- Output = list of visible vertices, correctly positioned
- Transform for eye-point - 4x4 Matrix Multiplications
  - Allows positioning with six degrees of freedom
- Lots of floating point operations!

Transform Processing

View Volume clipping and the Projection Plane

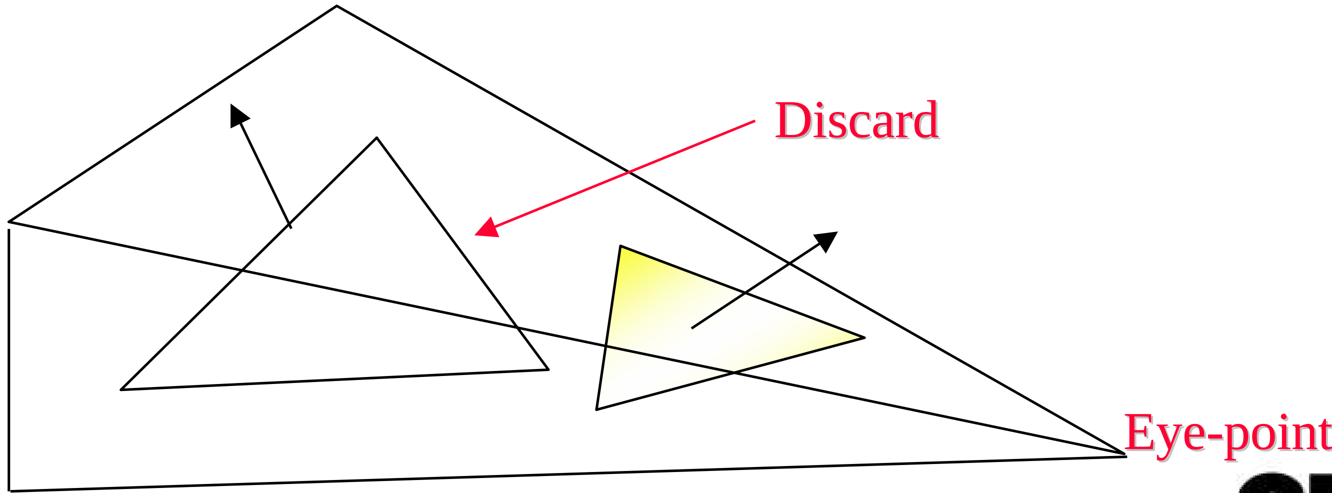


- Project onto Projection Plane - Trigonometry
- Clip against view volume - More Trigonometry

Geometry Efficiencies

View Volume Culling and Backface Culling

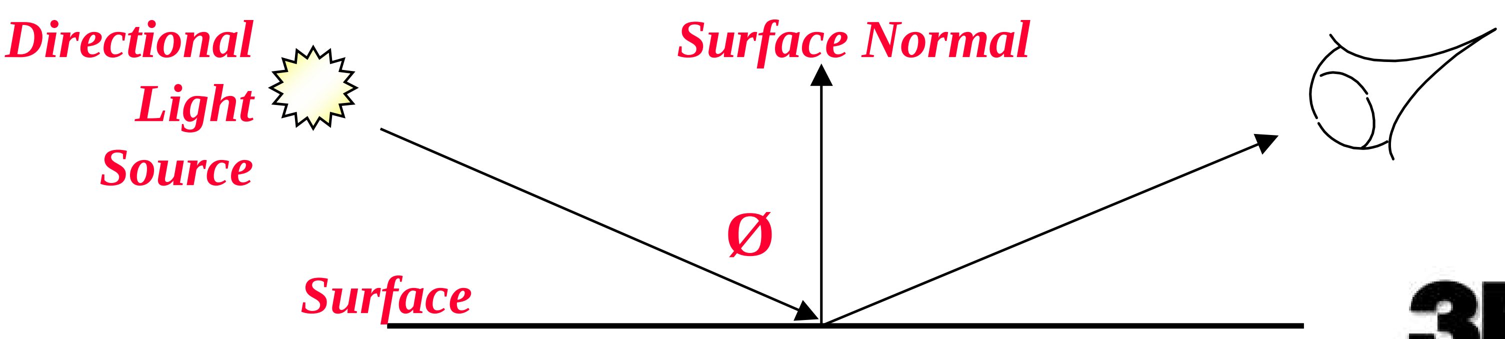
- View Volume culling can eliminate the majority of polygons in a scene trivially - it's behind you!
- The other big win is: Backface Culling
  - Normally polygons are "one-sided"
  - Polygons with normals pointing away from the eyepoint are invisible
  - The geometry pipeline can discard backfacing polygons
  - About 50% of the polygons in most real models are backfacing



Lighting Equation

Calculating the color of each vertex

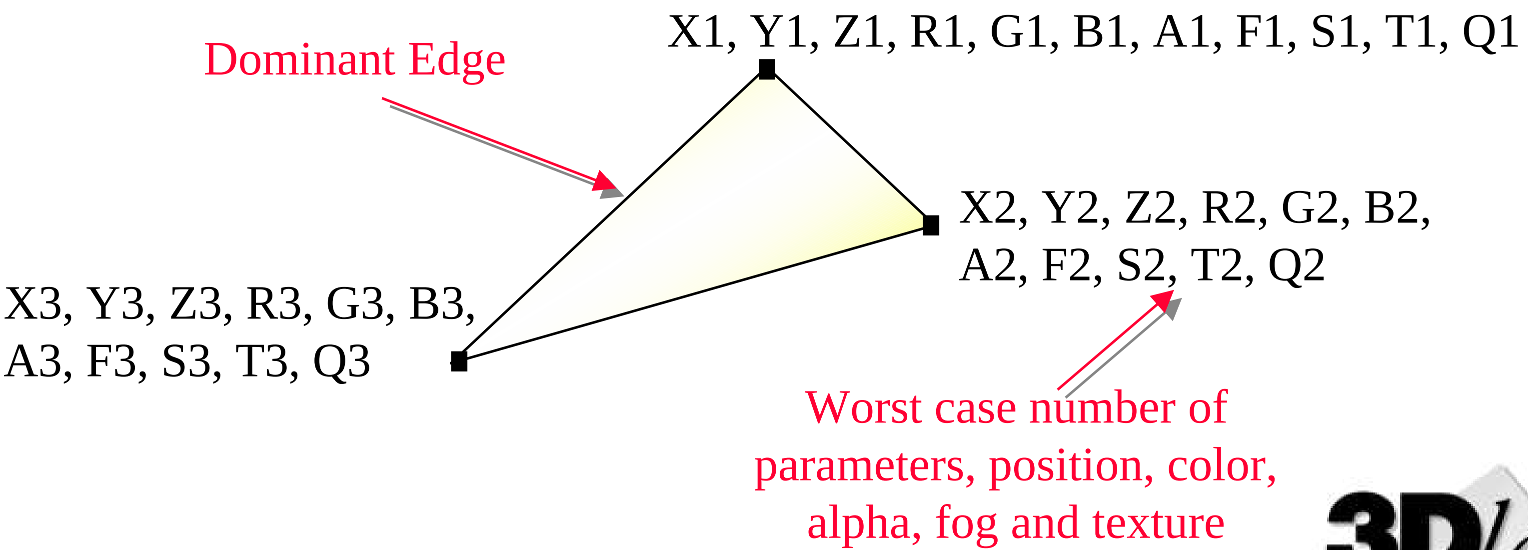
- Objects are lit by one or more light sources
  - Ambient light: non-directional, has a color
  - Directional lights: with position, direction and color
- Surfaces have reflective properties
  - Diffuse reflection coefficient: independent of angle
  - Specular reflection coefficient: depends on angle, gives glinting highlights
- Color - Ia.Ka + Id.Kf + Id.Ks.cosØ



Setup Calculations

Preparing for rasterization

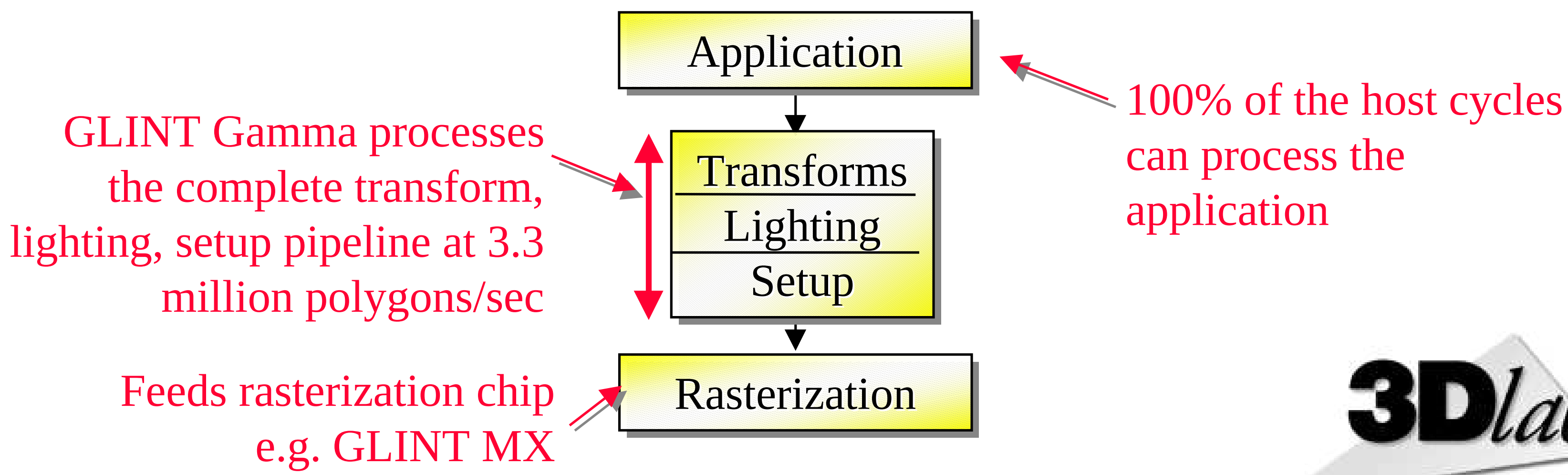
- Take screen coordinates of vertices
  - In floating point format
- Calculate slope and delta information
  - For each interpolant need to calculate StartI, dIdx, dIdyDom
- Converts to sub-pixel accurate fixed point format



GLINT Gamma

Complete Geometry Processing in a chip

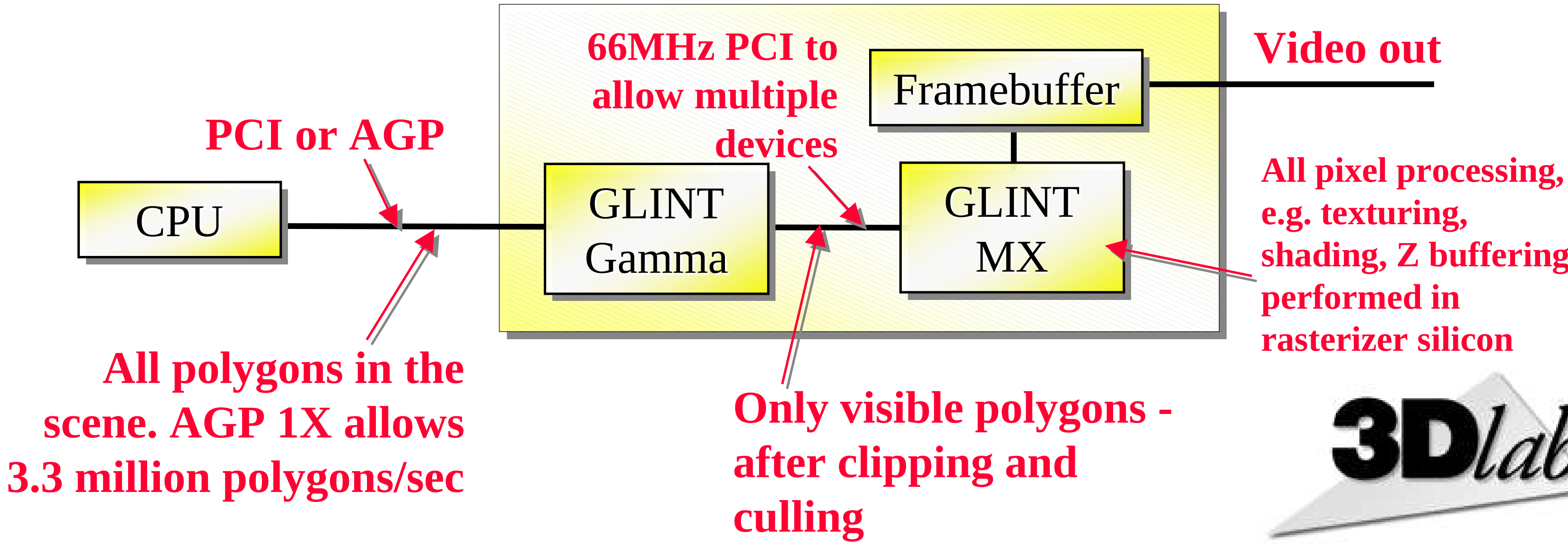
- GLINT Gamma integrates 100% of the geometry pipeline
  - At a price point suitable for PCs
- 3.3 million polygons/sec needs *2,000MFlops*
  - With full transformations and lighting enabled
  - 50% backface culled
- Host is free to process the application
  - GLINT Gamma will have a bigger effect on typical application performance than faster pixel fill-rates



System Design Using GLINT Gamma

Hardware preprocessing for rasterization silicon

- GLINT Gamma reads and processes polygon command stream
  - Outputs command stream for a rasterizer processor e.g. GLINT MX
- 33MHz PCI is not fast enough for host connection
  - Full 33MHz PCI bandwidth only supports 1.5 million polygons/sec
  - AGP enables the full 3.3 million polygons/sec performance
  - Need AGP's sideband addressing for optimized vertex fetching
- Use 66MHz PCI Connection to rasterizer
  - Can guarantee 66MHz on-board operation, and allows multiple devices



GLINT Gamma Functional Pipeline

Parameter fetch to fog

- Input DMA controller fetches parameters
  - Performs address translation
- OpenGL Begin/End paradigm
  - Points, Lines, Line loop, Line strip, Triangles, Triangle strip, Triangle fan, Quads, Quad strips
- Full geometry transformation processing
  - Vertex (View Model and Projection matrix)
- Texture Coordinate Generation
  - Spherical, Object linear, Eye linear
- Fog calculations
  - Linear, Exponential and Exponential Squared

Parameter Fetch
Primitive Processing
Transforms
Texture Coordinates
Fog Calculations
Clipping
Lighting
Setup

GLINT Gamma Functional Pipeline

Clipping to Setup

- Full Clipping
  - Frustrum clipping
  - Six user clip planes
  - Backface culling
- Full lighting calculations
  - Up to 16 Light sources
  - Soft degrade to unlimited number of lights
  - Point or directional lights
  - Local lights, Spot lights, Attenuated Lights
  - Two-side lighting
- Triangle, Line and Point Set Up
  - Same as GLINT Delta, but faster
  - Aliased or anti-aliased
  - Stippled or non-stippled

Parameter Fetch
Primitive Processing
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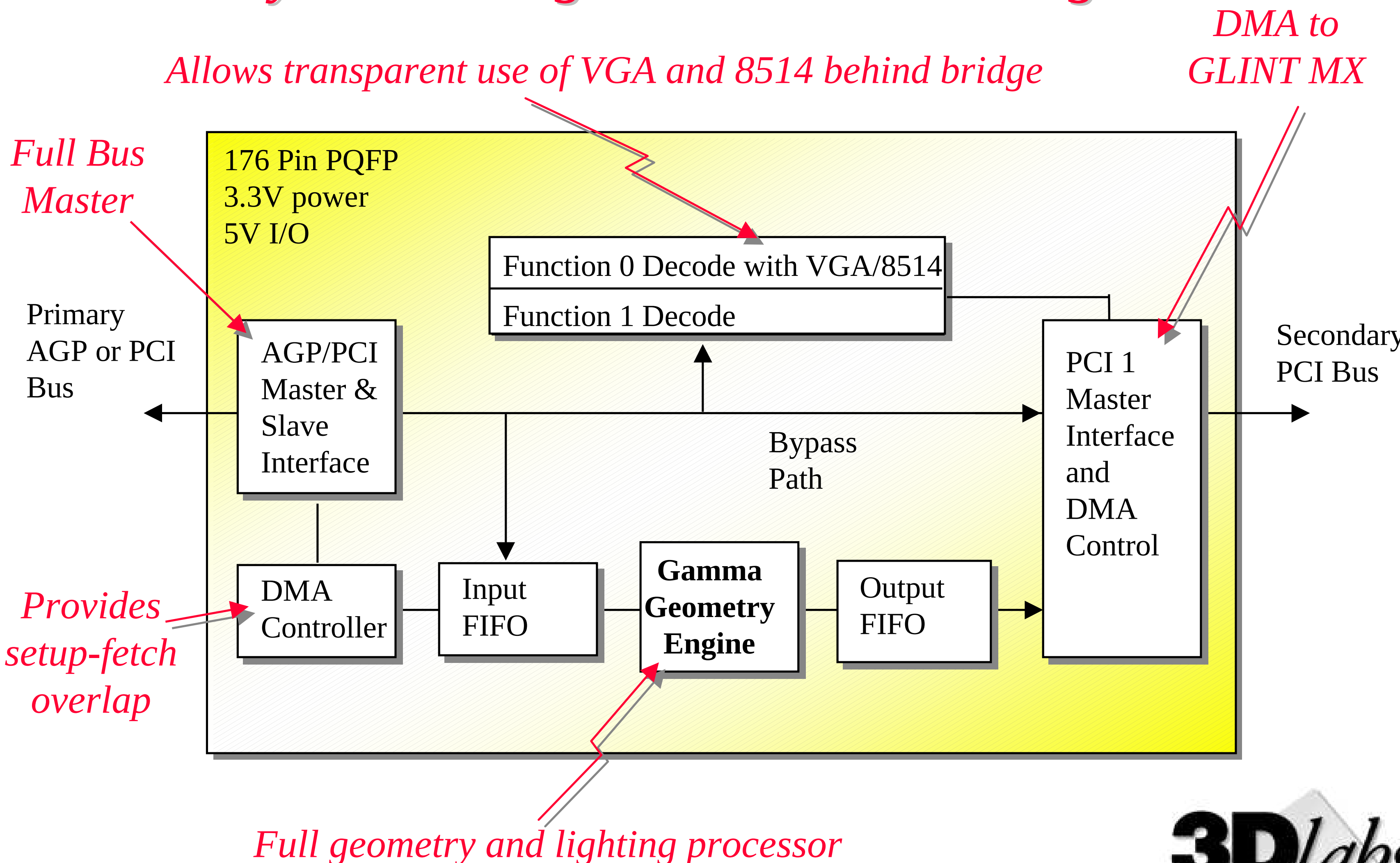
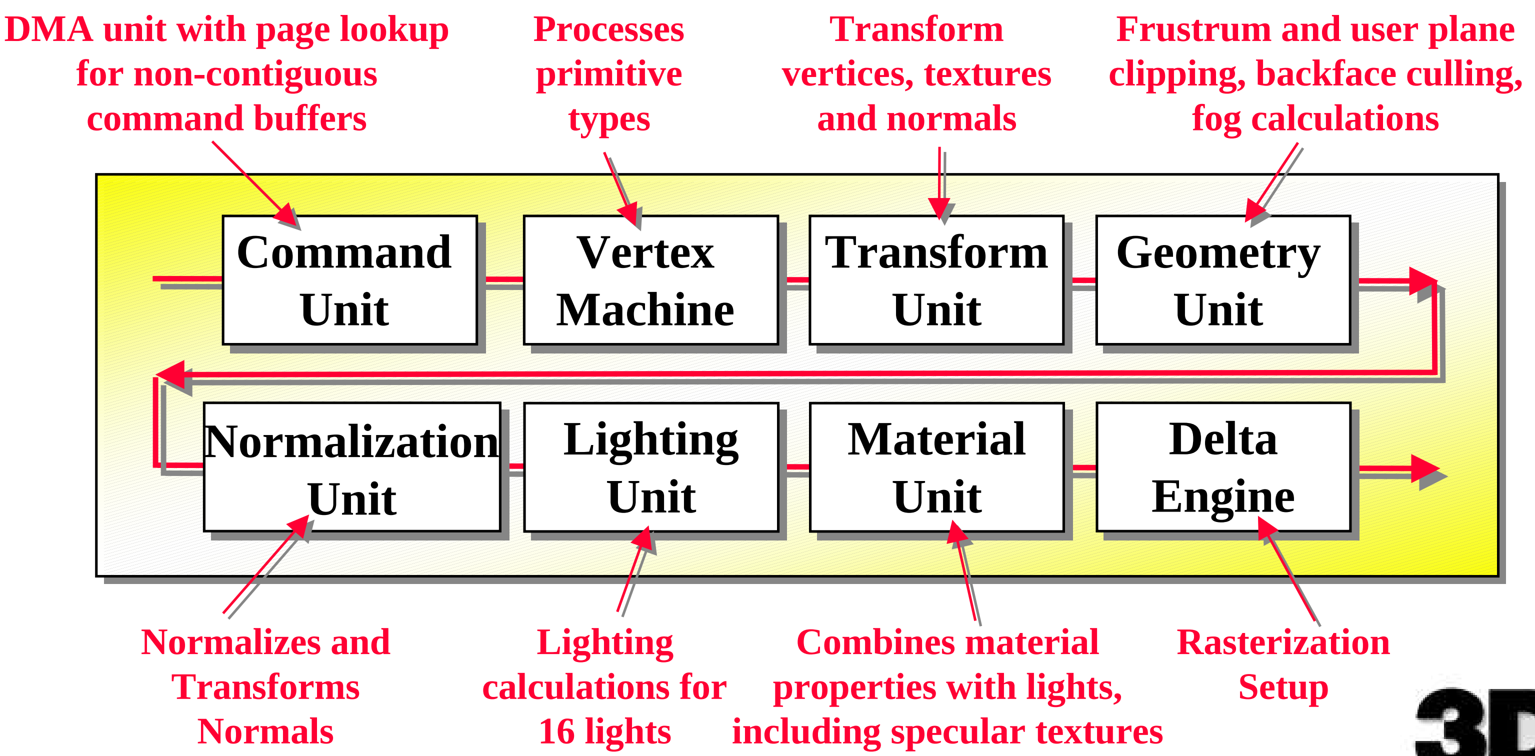
GLINT Gamma Architecture

Geometry Processing in a AGP/PCI Bridge



GLINT Gamma Pipeline

- Pipeline of function units
- Message passing protocol between units
- Each unit heavily-pipelined internally
- 150 total pipeline stages through the chip



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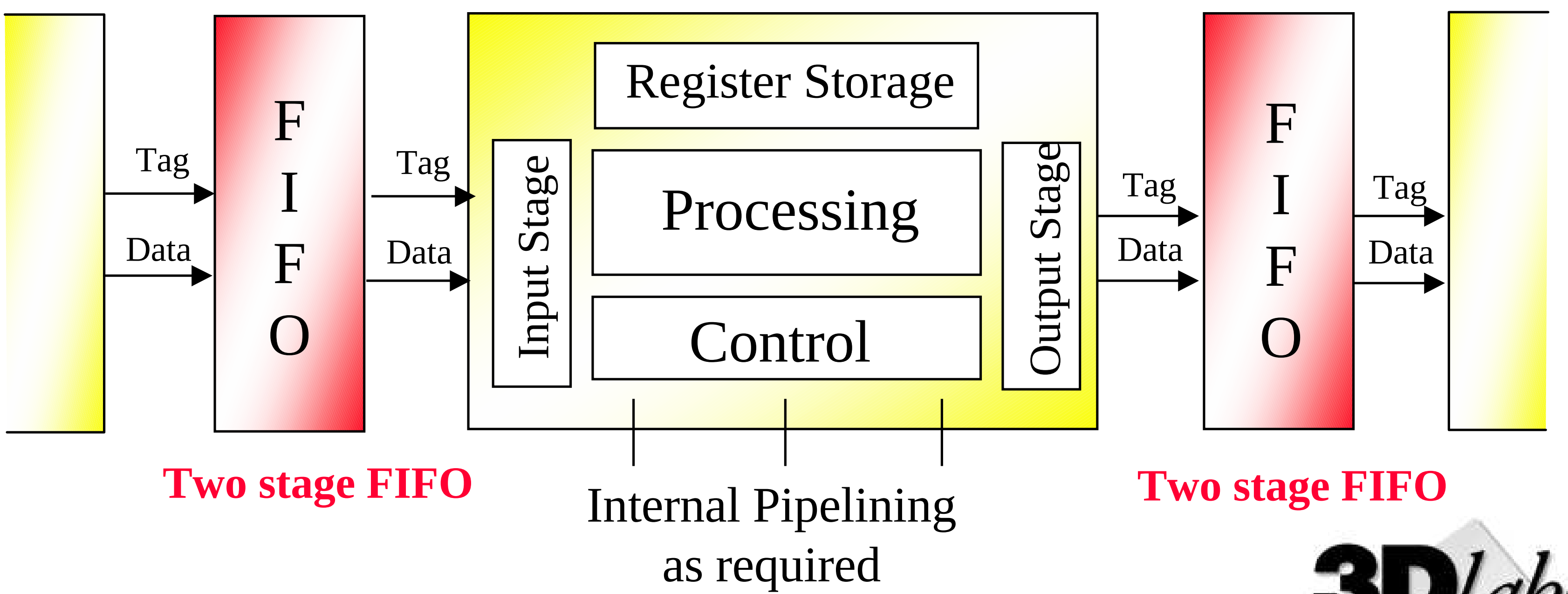
Function Unit Structure

- The unit pipeline uses a message passing paradigm
- A message is made up of a tag field and a data field
  - 11 bit tag identifies the message type
  - 128 bit data holds four 32 bit floats = complete vertex eg rgba or xyzw
- The unit processes each message according to message type



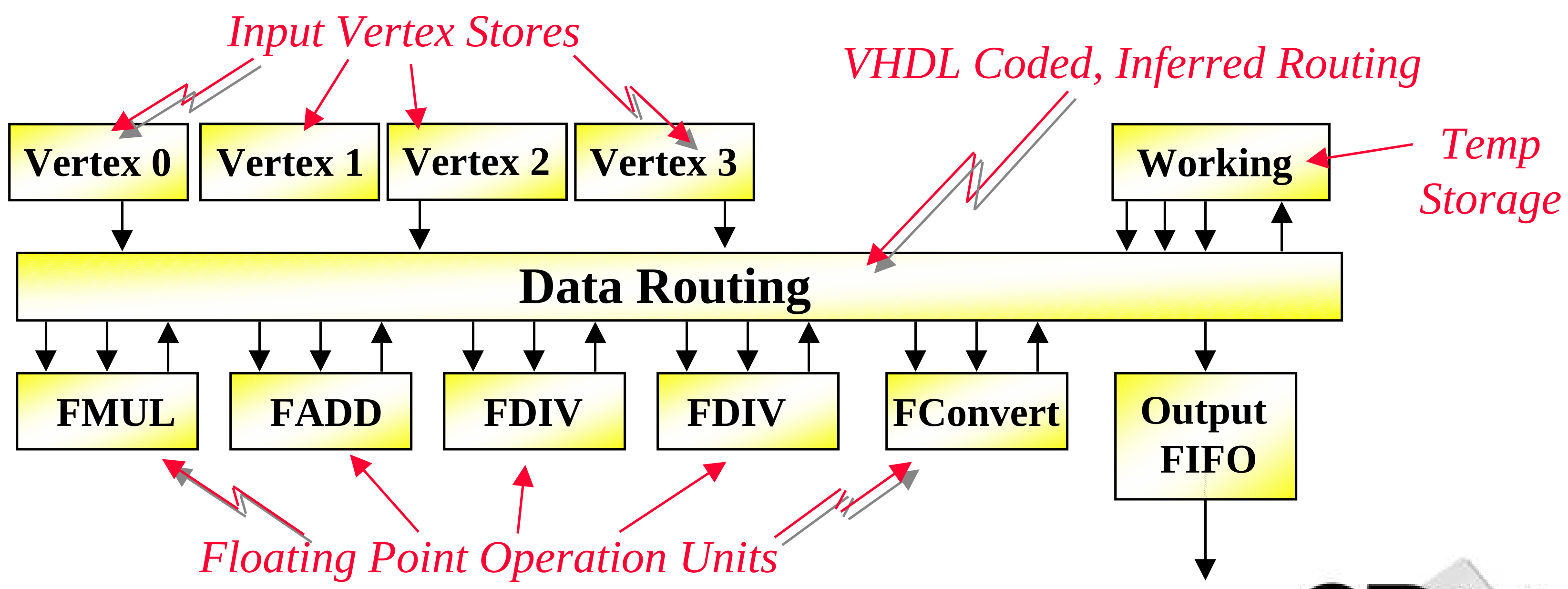
GLINT Gamma is Hardwired

Maximum performance per $

- 3D Geometry is well-understood
  - Don't need the luxury of programmability
- Functionality encompasses 100% of all key APIs
  - OpenGL 1.1, Direct 3D, Heidi and QuickDraw 3D
- Control in GLINT Gamma is a VHDL state machine
  - No RAM or ROM for program storage (less gates)
  - No program sequencer or instruction set (less gates)
  - No program fetch (less memory bandwidth)
- Data paths are inferred directly from VHDL
  - No general purpose routing costs
- 3Dlabs design technology enables devices of this complexity
  - Rapid conversion of floating point algorithms into hardwired silicon
  - Design tools first used to develop GLINT Delta

Typical Unit Processing Structure
Hardwired processing

- All operations are IEEE compatible
  - NAN handling not implemented
- Type and number of operation units varies from unit to unit



Total Floating Point Units

- All units are independent
- All units can be used simultaneously
  - No restriction on mix of operations
- Latency varies according to the unit

# Units	Type of Units	Throughput (cycles/result)
15	Multipliers	1
10	Adders,	1
25	Misc. conv. and comparators	1
4	Divide	5
1	Power	5
2	Inverse Square root	10

GLINT Gamma

Physical and Project Characteristics

- IBM CMOS 5S6 .35µ, 4 layer metal
- 176 pin PQFP
- 66MHz, 5 watts

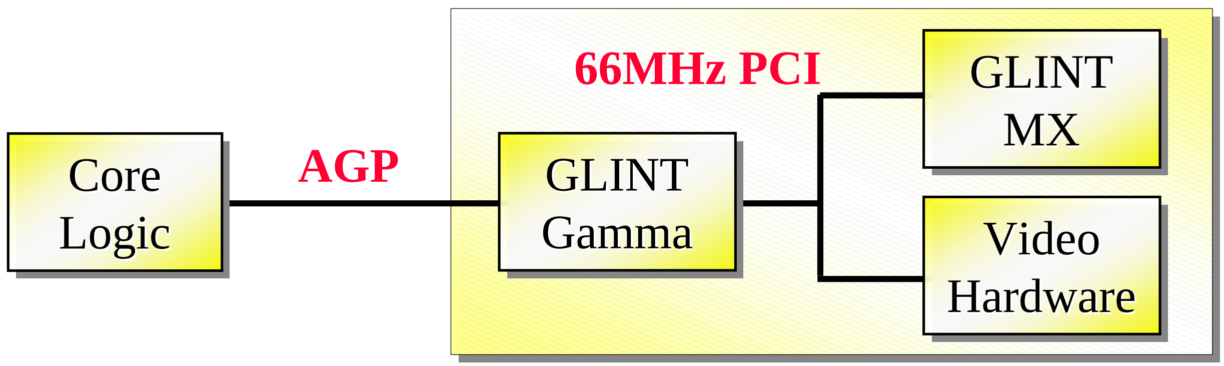
- 8 man years design time
- 600 page design specification

- Over 1 million gates
  - FP operators - 35%
  - Registers - 15%
  - Random logic - 50%

GLINT Gamma as AGP Bridge

Multi-function AGP Boards

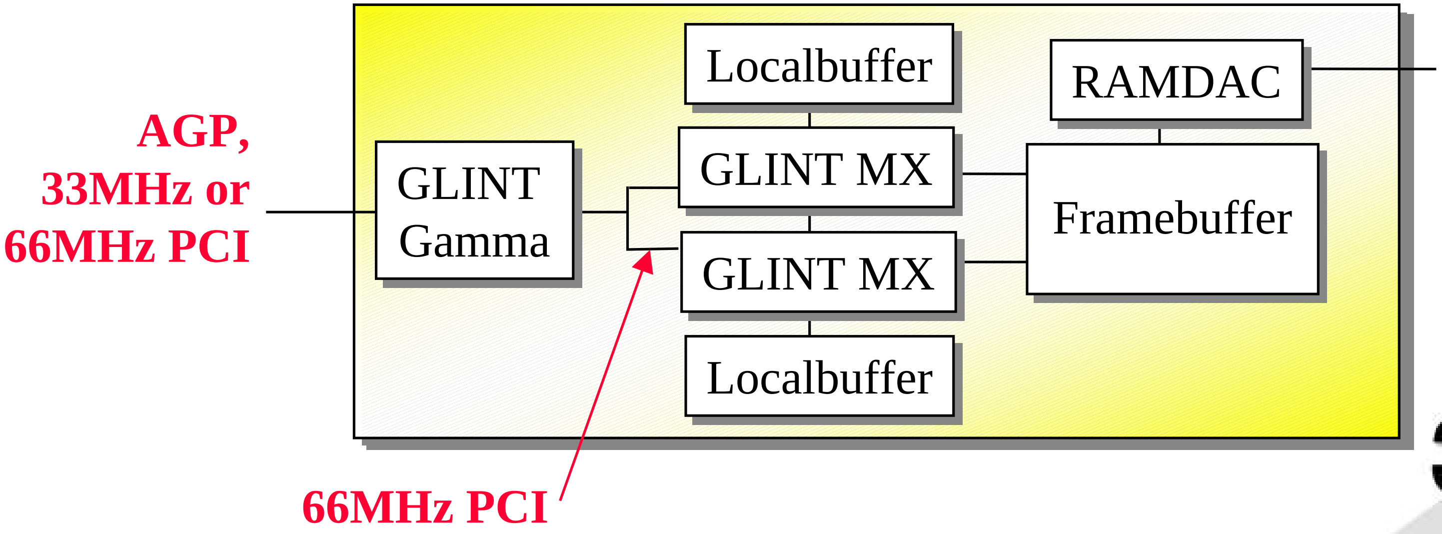
- AGP is point-to-point connection only
  - Only one slot and only one device on the AGP bus
  - Makes multi-functions on AGP problematic
- GLINT Gamma acts as a full AGP bridge
  - Multiple devices on an AGP board can access main memory
  - Via internal 66MHz PCI bus
- Enables multi-function boards
  - Uses for high performance video devices



Twin GLINT MX Design

A graphics pipeline well-matched with Pentium II

- GLINT MX is scalable from 2 to 8 processors
  - Transparently increases fill-rate
  - Interleaved scan-line rendering for effective load-balancing
- Pentium II -> GLINT Gamma -> Twin GLINT MX
  - Well-balanced application, geometry, rasterization pipeline
  - 2 Million visible, rendered polygons with full geometry processing
  - 66 Million Pixels/sec bilinear-mip-mapped filtered texture
  - 33 Million Pixels/sec trilinear-mip-mapped filtered texture



Summary

- 3D Geometry is floating point intensive
- It is the current bottleneck for increased 3D PC performance
- 3D geometry functionality is well understood and encapsulated in standard APIs
- It can be hard-wired for maximum performance per $
- GLINT Gamma implements the geometry and lighting for all key APIs - including OpenGL and Direct3D

