A HIGHLY-INTEGRATED WORKSTATION GRAPHICS SYSTEM

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Larry J. Thayer
Systems Technology Division
Hewlett-Packard Company

DESIRED FUNCTIONALITY

- Fast 2D Graphical User Interface (GUI)
- Digital video decompression support
- Efficient 3D graphics
PROJECT STRATEGY

- Cost/performance optimization through the use of system-level design (CPU hardware/Graphics hardware trade-offs)

- Performance optimization by pushing the limits of available technology

- Cost optimization through the use of a high level of integration

SYSTEM BLOCK DIAGRAM

CPU

GUI Accelerator

Frame Buffer Controller

Video Timing/ Cursor/ RAMDAC

Monitor

I/O Bus

32 data bits

RGB

Artist

Random port

Serial port

VRAM Array
1 or 2 Mbits (8 bits/pixel)
1. Can the function be performed more efficiently in the CPU?

2. Is the CPU enhancement inexpensive?

3. Is there a significant performance advantage by putting the function in the CPU?

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**GUI FEATURES**

**CPU (Hummingbird):**
- Fast memory → graphics path (block copy to I/O space)
- Fast register → graphics path (pipelined I/O store)

**Graphics (Artist):**
- Vector, rectangle, FB BitBlt, text, cursor HW
- Bit/pixel FB access mode, VRAM block write
- Boolean raster operations
- Two look-up tables
DIGITAL VIDEO DECOMPRESSION FEATURES

CPU (Hummingbird):

- Special image processing instructions
- Fast register → graphics path

Graphics (Artist):

- Color space conversion hardware
- Color compression into the frame buffer

IMAGE DECOMPRESSION PIPELINE
COLOR COMPRESSION/DECOMPRESSSION QUALITY

24 planes  8 planes dithered  8 planes with Color Compression

3D GRAPHICS FEATURES

CPU (Hummingbird):

☐ Transformations, clipping (polygons and vectors)

☐ Lighting, Z buffering, pixel color interpolation (polygons)

Graphics (Artist):

☐ Vector rasterizer hardware

☐ Color compression into the frame buffer
MAXIMIZING PERFORMANCE

- Fast hyper page mode: 37.5 nsec
- Utilizing advanced VRAM features
- Pixel block write speed: 850 MPixels/sec (constant-color)

GRAPHICS SYSTEM PERFORMANCE

<table>
<thead>
<tr>
<th>Operation</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large rectangle fill (pixels/sec)</td>
<td>850 M</td>
</tr>
<tr>
<td>Vectors/sec (10-pixel random)</td>
<td>2.1 M</td>
</tr>
<tr>
<td>10×10 rectangles/sec</td>
<td>1.7 M</td>
</tr>
<tr>
<td>Text (6×13 characters/sec)</td>
<td>1 M</td>
</tr>
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<td>FB Bit BLT (unaligned pix/s)</td>
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HIGH LEVELS OF INTEGRATION

- Built-in DAC connects directly to a monitor
- Built-in programmable PLL eliminates a crystal and allows flexibility to change resolutions
- JTAG port and multiple internal signature generators
- Mixed custom/standard cell design

ARTIST FACTS

<table>
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<tr>
<th>Number of Transistors</th>
<th>525,000</th>
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<tr>
<td>Equivalent gates</td>
<td>313,000</td>
</tr>
<tr>
<td></td>
<td>(108,000 without RAM)</td>
</tr>
<tr>
<td>Die size (Step size)</td>
<td>9.7 × 12.1 mm</td>
</tr>
<tr>
<td>Package</td>
<td>208-pin metal QFP, or 240 MQFP with flat panel out</td>
</tr>
<tr>
<td>Metal layers</td>
<td>3 (aluminum)</td>
</tr>
<tr>
<td>L_eff</td>
<td>0.61 μm (nFETs)</td>
</tr>
<tr>
<td></td>
<td>0.66 μm (pFETs)</td>
</tr>
<tr>
<td>Frequency of operation</td>
<td>40 – 80 MHz (GUI/RAM ctl)</td>
</tr>
<tr>
<td></td>
<td>25 – 135 MHz (video control)</td>
</tr>
<tr>
<td>Power</td>
<td>3.5 W (worst case)</td>
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ARTIST BLOCK DIAGRAM

I/O Bus 32 bits muxed addr/data RGB Analog Out

Bus Interface
Input FIFO
GUI Accelerator (vectors, rectangles, text, BLTs)

State Registers
Color-Space Convertor
Pixel formatter
Tile Builder
Read Ahead FIFO
VRAM Interface

LUT RAMs
Color Decompression

PLL
Test

Pixel I/O Data Path
LUT sel/cursor ctl

Decompression, Cursor, LUT sel RAM

VRAM ctrl Video Timing

VRAM Random Port VRAM Serial Port

ARTIST DIE PHOTOGRAPH
SUMMARY

By using a system-level design approach and high levels of integration, a powerful yet inexpensive workstation graphics system has been built. This system accelerates 2D GUI functions, digital image decompression, and 3D graphics.