ASTC: The Future of Texture Compression

Kevin Ho
ARM Taiwan FAE
Graphics: It’s all about the textures
A Universal Tool

Reflectance

Illuminance

Normals

Gloss, Height, etc

3D Properties

Lighting environment

The Architecture for the Digital World
But There’s a Problem…

Textures are big
- Memory footprint and bandwidth
- Performance and power

We need texture compression!
How Texture Compression Works

Image is divided into blocks
- E.g. 4x4 pixels

Encode blocks as bit strings
- Fixed length, e.g. 64 bits / block
- Fixed rate, lossy encoding
- Bpp = bits per block / pix per block
- Constant-time random access

Everybody does this
- DXTn, RGTC, BC7, PVRTC…
What Kind of Compression System Do We Need?

Textures are used for many different things:

- Reflectance
- Gloss, Height, etc
- Normals
- Illuminance
- Lighting environment
- 3D Properties

Each use has its own requirements

- Number of color components
- Dynamic range (LDR vs HDR)
- Dimensionality (2D vs 3D)
- Quality (≈ bit rate)
Compression Today

Microsoft® DirectX®

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Compression Today

Imagination Technologies® PVRTE™

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Compression Today

OpenGL® ES™ 3.0

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Compression Today

Putting them all together

<table>
<thead>
<tr>
<th>Bits per pixel</th>
<th>Color components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BC4, EAC</td>
</tr>
<tr>
<td>2</td>
<td>BC5, 2xEAC</td>
</tr>
<tr>
<td>3</td>
<td>BC1, ETC2, PVRTC</td>
</tr>
<tr>
<td>4</td>
<td>PVRTC</td>
</tr>
<tr>
<td></td>
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</tbody>
</table>

ETC2+EAC

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Compression Today: Observations

What a mess!
- Horribly fragmented
- Many formats are proprietary
- Must recondition / requalify assets for every format

Where’s my use case?
- Only one low-bit-rate format (PVRTC RGB/RGBA, 2bpp)
- Only one HDR format (RGB, 8bpp)
- Poor support for 1 and 2 channel images
- Very coarse quality / size tradeoff
Introducing ASTC

Adaptive Scalable Texture Compression

- Created by ARM in response to a Khronos competition
- …with a valuable technical contribution from AMD

Functionality

- Scalable bit rate: 8bpp down to <1bpp in fine steps
- Orthogonal choice of base format (L, LA, RGB, RGBA)
- Both LDR and HDR pixel formats
- Both 2D and 3D textures
- Very high quality
**ASTC Bit Rates**

Block-based paradigm generalized to 3D

- Fixed block size of 128 bits
- Bit rate determined by block size

<table>
<thead>
<tr>
<th>Block Size</th>
<th>2D Bit Rate</th>
<th>Block Size</th>
<th>3D Bit Rate</th>
<th>Block Size</th>
<th>3D Bit Rate</th>
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<tbody>
<tr>
<td>4x4</td>
<td>8.00 bpp</td>
<td>10x5</td>
<td>2.56 bpp</td>
<td>3x3x3</td>
<td>4.74 bpp</td>
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<tr>
<td>5x4</td>
<td>6.40 bpp</td>
<td>10x6</td>
<td>2.13 bpp</td>
<td>4x3x3</td>
<td>3.56 bpp</td>
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<td>5.12 bpp</td>
<td>8x8</td>
<td>2.00 bpp</td>
<td>4x4x3</td>
<td>2.67 bpp</td>
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<tr>
<td>6x5</td>
<td>4.27 bpp</td>
<td>10x8</td>
<td>1.60 bpp</td>
<td>4x4x4</td>
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<td>1.60 bpp</td>
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<td>2.67 bpp</td>
<td>12x12</td>
<td>0.89 bpp</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Compression Today

Putting it all together

- **PVRTC**
  - 1 color component
  - 2 bits per pixel

- **ETC2**
  - 2 color components
  - 4 bits per pixel

- **ETC2+EAC**
  - 2 color components
  - 6 bits per pixel

- **BC1**
  - 2 color components
  - 3 bits per pixel

- **BC1**
  - 1 color component
  - 4 bits per pixel

- **BC2,3,7**
  - 5 bits per pixel

- **BC7**
  - 2 color components
  - 5 bits per pixel

- **BC6H**
  - 1 color component
  - 5 bits per pixel

- **BC5**
  - 2 color components
  - 6 bits per pixel

- **2xEAC**
  - 2 color components
  - 7 bits per pixel

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Compression Today

All current LDR formats

[Graph showing the relationship between color components and bits per pixel]
Compression Today

All current LDR formats

ASTC 2D LDR

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Compression Today (HDR)

All current HDR formats

![Graph showing the relationship between bits per pixel and color components for HDR formats. The graph has a single data point at (8, 1).]
Compression Today (HDR)

All current HDR formats

ASTC 2D HDR

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Compression Today (3D)

NVIDIA VTC

![Graph showing compression compared to NVIDIA VTC. The x-axis represents bits per pixel, and the y-axis represents color components. The graph shows that NVIDIA VTC outperforms in terms of compression at lower bits per pixel and higher color components.]
Compression Today (3D LDR)

NVIDIA VTC

ASTC 3D LDR

color components

bits per pixel

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Quality Comparison – RGB LDR 2bpp

24 natural images

- ASTC vs PVRTC at 2bpp
Quality Comparison – RGB LDR Medium Bit Rate

24 natural images
- ASTC 3.56 bpp vs S3TC at 4bpp
Quality Comparison – RGB LDR Medium Bit Rate

24 natural images
- ASTC vs BC7 at 8bpp
Quality Comparison – RGB HDR High Bit Rate

Selected OpenEXR example images
- ASTC vs BC6H at 8bpp
Quality Comparison - Example

ASTC at 3.56 bpp vs S3TC at 4 bpp

- 2.8 dB PSNR advantage
Quality

original

PVRTC
2bits/pixel

ASTC
2bits/pixel
High Dynamic Range Support

EXR Tree test image compressed and decompressed at 8 bits/pixel

HDR support better than BC6H in many cases – the current de facto standard.
High Dynamic Range Support

EXR *Spirals* test image compressed/decompressed at 8 bits/pixel
Support - Hardware

ASTC will be supported in all upcoming ARM® GPUs

Currently available in
- ARM Mali™-T624 and Mali-T628
- ARM Mali-T678

Partner silicon is on the way
Support – Documentation and Tools

How and why it works


Evaluation codec (source)


* Now supported across the Mali development tool chain

- Mali Texture Compression Tool
- Mali OpenGL ES 3.0 Emulator
Support – Standards

ASTC LDR subset defined to promote fast adoption
- No 3D, no HDR
- Pure subset – fully compatible with a full ASTC decoder

ASTC LDR extension approved by The Khronos Group
- KHR_texture_compression_astc_ldr
- Defined for both OpenGL® and OpenGL ES™
ARM Mali Compression Tools
Summary

- ARM is leading the mobile graphics industry
- Setting the standard
- Best in class compression at all bit rates, for all content types
- More bit-rate options than every other format put together
  - ...and then some
- Support for widest range of use cases
  - 2D and 3D textures
  - Low and high dynamic range
- Low area cost
- Lower bit-rates save more energy
- Already has widespread support within the industry
Thank you!

malideveloper.arm.com