High Performance Displays for AR/VR Applications

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Agenda

Introduction to AR/VR and HMD form factor trends

Arm Display Solution Overview

Arm Mali Mira DPU: processing for HMDs

AR/VR display ecosystem
Key AR/VR Technology Areas

Display
- Panel & Processor
- Graphics & Video
- Environment Mapping

Tracking Mapping
- Pose/Position/Area
- Gesture/Controller/Eye
- Optical Flow
- Global Sync

ML/CV
- Object Classification
- Object tracking
- Voice Control (NLP)
AR/VR Display Form Factors

- **Smartphone AR/VR**
  - Device: ~5 Watt
  - SoC: 3.5 Watt

- **All-In-One VR**
  - Device: ~5 Watt
  - SoC: 3.5 Watt

- **Companion AR/VR**
  - Host (Mains power)
  - AR HMD: <0.5W
  - VR HMD: <5W

- **Dual device AR/VR**
  - Host device: 5 Watt
  - Client device: <= 0.5W

- **All-In-One AR**
  - Device: < 0.5 Watt
HMD requirements
Driven by higher display resolutions and low latency for truly immersive AR/VR

2018
- 2880 x 1440 @ 90 Hz
- Pulsed illumination: 1-2 ms
- Motion to photon latency <20ms
- Wide FOV 90-110°

2019
- 4320x2160 @ 90 fps
- 3600x1800 @ 120 fps
- 10bpc depth
- Inside-Out tracking

>2020
- >5120x2560 @ 120 fps
- Inside-out-positional tracking with room scale VR
- New AR display technologies
- FOV 140°
Arm Mali Mira
DPU: AR/VR
Processing for
Head Mounted Displays
## Arm Display Solution Target Markets

<table>
<thead>
<tr>
<th></th>
<th>LSC</th>
<th>Premium</th>
<th>Mass market</th>
<th>Home</th>
<th>AR/VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mali</td>
<td>Mali-D71 AD5</td>
<td>Mali-D71/Mira AD5</td>
<td>Mali-D51 Mira Lite, AD3</td>
<td>Mali-D71 AD5</td>
<td>Mali Mira AD5</td>
</tr>
</tbody>
</table>

![Diagram showing the target markets and Arm Display Solutions](image-url)
Arm Mali-D71 Overview
Delivering 4K120 Performance for Next Generation Premium Devices

Compared to Mali-DP650

2x Performance (up to 4K120)

2x Scene Complexity

8 composition/rotation and 4 scaled layers

50% better memory latency

MMU-600, AFBC1.2 on all layers, internal TBUs

Mixed HDR and SDR composition targeting any HDR/SDR panel

When combined with Assertive Display 5

Same area
Arm Assertive Display 5 (AD5) Overview

- Best viewing experience under all light conditions (ambient light adaptation)
- World’s best local tone mapping engine – Iridix™
- High-quality SDR/HDR colour volume mapping and tone mapping for any display
- Assertive Content Backlight Control – display subsystem power minimization

Assertive Display Off  Assertive Display On
Mixed HDR and SDR Content Handling with Mali-D71 + AD5

HDR10 video (ST.2084, BT.2020)

sRGB UI (BT.1886, BT.709)
Mali Mira - Features beyond Mali-D71

Lens Distortion Correction (LDC) and Chromatic Aberration Correction (CAC) for HMDs

Asynchronous TimeWarp (ATW) based on up-to-date head tracking

Composition of up to 4 AR/VR layers (head-locked or head-tracked)

Premium and mainstream mobile and other HMD variants

- Mali Mira – optimized for 4320x2160 @ 90Hz (4K120 capable)
- Mali Mira lite – optimized for 2880x1600 @60Hz (4K60 capable)
Lens Distortion Correction

1024x1024 pixels
Lens Distortion and Chromatic Aberration Correction

1024x1024 pixels
Mali Mira Example Translations – RGB Eye Buffer

Optimized for Head Mounted Displays

- **Lens Distortion Correction**
- **Asynchronous TimeWarp**
- **Chromatic Aberration Correction**
- **Z-rotation 20°**

**Example Translations**

1. **1024x1024 RGB32**
   - **1440x1440 FOV 90°**

2. **1024x1024 RGB32**
   - **1440x1440 FOV 120°**

3. **1024x1024 RGB32**
   - **1440x1440 FOV 90°**

   - **Lens Distortion Correction**
   - **Asynchronous TimeWarp**
   - **Chromatic Aberration Correction**
   - **X-rotation 45° Z-offset 0.5**
Mali Mira Example Translations – YUV Eye Buffer
Optimized for Head Mounted Displays

- 3840x2160 YUV10
  - 2160x2160 FOV 120°
  - Lens Distortion Correction
  - Asynchronous TimeWarp
  - Chromatic Aberration Correction
  - Y-Rotation 45° Z-Rotation 20°
  - X-offset 0.3

- 1920x1080 YUV10
  - 1440x1440 FOV 90°
  - Lens Distortion Correction
  - Asynchronous TimeWarp
  - Chromatic Aberration Correction
  - Y-Rotation 45° Z-offset 0.5

- 1920x1080 YUV10
  - 1440x1440 FOV 90°
  - Lens Distortion Correction
  - Chromatic Aberration Correction
  - Quad-projection 720p
Mali Mira – video snapshot from FPGA demo
Mali Mira and Mali Mira Lite Overview
Adds Asynchronous TimeWarp Units (ATU) Block for immersive headset experience

Mali Mira & Mali Mira lite block diagram

Features

4K120 (4K60*) performance
2160x2160 input eye buffer size
8 (4*) composition layers per scene
4 (2*) AR/VR layers per eye per scene
SW programmable on/off per AR/VR layer

Asynchronous TimeWarp, Lens Distortion Correction, Chromatic Aberration Correction, Clamp-to-edge, Global Vignette

Projection and Quad layer types

*when configured as Mali Mira Lite
Mali Mira Premium Mobile Value: SoC Power Savings
Based on Gunjack (1x App layer + 1x UI layer)

Bandwidth Gains

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Bandwidth GB/s (LDC, CAC, ATW on GPU)</th>
<th>Bandwidth GB/s (LDC, CAC, ATW on Mira)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQHD@90FPS</td>
<td>4.13</td>
<td>2.64</td>
</tr>
<tr>
<td>WQHD@120FPS*</td>
<td>4.3</td>
<td>2.32</td>
</tr>
<tr>
<td>4K@60FPS</td>
<td>6.19</td>
<td>3.96</td>
</tr>
<tr>
<td>4K@90FPS**</td>
<td>9.28</td>
<td>5.98</td>
</tr>
</tbody>
</table>

Power Gains (SOC+DRAM)

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Power (Watts) (LDC, CAC, ATW on GPU)</th>
<th>Power (Watts) (LDC, CAC, ATW on Mira)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WQHD@90FPS</td>
<td>1.62</td>
<td>1.4</td>
</tr>
<tr>
<td>WQHD@120FPS*</td>
<td>1.33</td>
<td>1.08</td>
</tr>
<tr>
<td>4K@60FPS</td>
<td>2.08</td>
<td>1.65</td>
</tr>
<tr>
<td>4K@90FPS**</td>
<td>2.7</td>
<td>2.33</td>
</tr>
</tbody>
</table>

* GPU render rate is 60fps
** GPU render rate only hits 85 fps when LDC, CAC, ATW is run on GPU only due to TDP limit
Mali Mira Mainstream Mobile Value – Area Efficiency

Using Mali Mira Lite allows moving processing from the GPU to the Display Processor.

Lower GPU performance requirements and allowing for a lower area GPU solution.

Unlocking VR for mainstream mobile devices.

AREA COMPARISON

- 2K Gunjack @ 60/90Hz
  - Mali-G76 6-core, 256KB L2, Mali-D51
  - Mali-G51 2-core, 128KB L2, Mira Lite

Comparison: Mali-G76 vs Mali-G51
Mali Mira Benefits: Smartphone Driven and All-In-One

**GPU Based AR/VR Processing**
- 20% of GPU cycles
- Extra read/write pass through DDR
- Higher motion to photon latency
- Lower pixel resolution and lower framerate

**DPU Based AR/VR Processing**
- >20% power saving per AR/VR layer
- >35% DRAM bandwidth saving
- >50% area efficiency for AR/VR
- 2kx2K per eye @ 120 max performance within mobile SoC power budget
**System Topology for Companion HMDs**

**HMD SoC possible topology**

- **CPU**
- **Vision Processor**
- **ISP**
- **ML**
- **Mira Display**
- **Video**
- **Sensor Hub**
- **Security**
- **Interconnect**
- **Wireless Connectivity**
  - High Bandwidth
  - Low Power
  - Low Latency

**Mali Mira Lite Benefits**

Could eliminate need for GPU (DPU is a fraction of the area) whilst still providing flexibility by means of software for i.e.

- Gamma/de-gamma, colour management
- Lens distortion strength, distortion mesh,
- Chromatic aberration on/off
- ATW on/off
Foveated Mipmaps

High quality lens-matched shading

Multi-resolution rendering

Reduces GPU fragment shading and overall bandwidth

Mali Mira can blend up to 4 mipmaps for final AR/VR scene
Arm Display Ecosystem Engagements

Arm Mali Display team work closely with major AR/VR display PHY, DDIC & panel vendors to provide complete and optimized solutions.

Arm Mali Display team works with various companies & standards bodies to enable better AR/VR experiences and to reduce the complexities of porting & integration.
Summary

- Arm offers a range of Display Solutions for Premium and Mainstream mobile, LSC and Home devices
- Arm’s new display offering “Mali Mira” targets Head Mounted Displays (HMDs) for AR/VR applications
- Mali Mira offloads the GPU from performing Lens Distortion Correction (LDC), Chromatic Aberration Correction (CAC) and Asynchronous TimeWarp (ATW) leading to:
  - Significant mobile power savings and quality improvements for AR/VR content on HMDs
  - Premium AR/VR HMD performance to the area constrained mainstream market

SEE MALI MIRA IN ACTION IN THE DEMO AREA
Thank You
Danke
Merci
谢谢
ありがとうございます
Gracias
Kiitos
감사합니다
धन्यवाद
תודה
Enabling AR/VR in Mobile

- Diverse and innovative devices
- Developing Standard APIs and HALs
- A rich and evolving ecosystem
- Continuous delivery of new and exciting experiences

Platforms

Silicon/Technology Vendors

OEM/ODM/Tech

Frameworks/Middleware

Developer Ecosystem