Digital TV (DTV) Market Trends and DRAM Requirements

October 2015
Agenda

• Key Features and Technology Trends
• DTV System and SoC Architecture
• DRAM Memory Usage in DTVs
• DRAM Market Model for DTVs
Key Features Trends

- Resolution and screen size increasing
- Expectations of PC-like experience (graphics, Internet, browsing)
- More human interface
- CPUs need more multi-tasking

2010
- LCD, PDP TV, and CRT TV
- Max FHD resolution
- Major screen size less than 50”

2015
- Consolidation to LCD TV
- 60Hz/120Hz TV
- Smart TV + web browsing
- 3D TV, 2D→3D TV, 3D graphic
- USB host
- Complex FRC; video processing requires powerful CPU

2018
- Quantum Dot TV and OLED TV
- 24% of 4K TV
- Up to 240Hz TV
- PC-like Internet/web browsing experience
- More human interface
- Bigger screen sizes 70”-100”
- Multi tasking CPU for complicated decoding/processing power

Source: Micron and Industry Analysts
DTV Market Trends in 2015

Responding Positive 4K TV Market
• Forecasting 60Mu 4K TVs in 2017
• Various positioning, high-end to mainstream 4K TVs
• Continuous effort to reduce 4K TV price

Formed “UHD Alliance” in 2015
• Built Ecosystem, Key TV Makers Filmmakers & Content Providers: Samsung, LG, Sony, Panasonic, Sharp Walt Disney, WB, 20th Century Fox, Netflix
• Collaborating to accelerate UHD Adoption

More 4K Content Providers

<table>
<thead>
<tr>
<th>Provider</th>
<th>Date</th>
<th>Supported UHDTV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netflix</td>
<td>4/14</td>
<td>SS, LG, Panasonic, Sony, Vizio</td>
</tr>
<tr>
<td>Amazon</td>
<td>10/14</td>
<td>Samsung, LG, Sony 4K, Vizio</td>
</tr>
<tr>
<td>M-Go</td>
<td>11/14</td>
<td>Samsung 4K UHD</td>
</tr>
<tr>
<td>Sony Video</td>
<td>7/14</td>
<td>Sony</td>
</tr>
<tr>
<td>Comcast</td>
<td>12/14</td>
<td>Free to XFINITY (VOD)</td>
</tr>
<tr>
<td>Direct TV</td>
<td>11/14</td>
<td>SS UHD, DirectTV Genie HD DVR (VOD)</td>
</tr>
<tr>
<td>YouTube</td>
<td>2014</td>
<td>Computer with 4K (VOD)</td>
</tr>
</tbody>
</table>

Need more memories (Gb/Set & Bandwidth/set) as UDH TV gets better video and graphics

~3GB density per set
~45GB/s bandwidth
8/16GB e.MMC/set

Many Operating System from 2015 DTV
• Major TV makers have their own TV Operating System
• TV becomes smarter and smarter: requires optimized operating system to support faster TV processor
• Korea: Samsung-Tizen, LG-WebOS2
• Japan: Sony-Android TV, Panasonic-Firefox
• China: Alibaba - Yun OS, Tencent - TOS+, Xiaomi: MIUI, Baidu - own Baidu’s OS

Increasing Mix of Memories Drives DRAM TAM High

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gb/Set</td>
<td>% Mkt</td>
</tr>
<tr>
<td>Low</td>
<td>1.4</td>
<td>56%</td>
</tr>
<tr>
<td>Mid</td>
<td>6.8</td>
<td>39%</td>
</tr>
<tr>
<td>High</td>
<td>20.2</td>
<td>5%</td>
</tr>
<tr>
<td>Gb/Set</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

24% TV set drives 50% of DTV DRAM TAM in 2018
UHD Alliance

• Challenges for 4K UHD today...
  - Optimized content
  - Delivery methods
  - Content coding/decoding
  - Bandwidth concerns

• UHD Alliance Announced During CES 2015
  - Goal of UHD Alliance
    - Set premium quality standards for UHD 4K content, delivery, and establish a "healthy UHD ecosystem"
    - Make sure the content looks really good, figure out how it's delivered, including next-generation features such as HDR, Wide Color Gamut, High Frame Rate, and immersive 3D audio
    - Determine best way to enable production, distribution and consumption of content and playback capability of devices
  - TV brands, Hollywood film studios, content distributors and technology companies come together
  - Movie studios hope the alliance can help make video look better, will benefit true UHD experience by identifying products and content

Formed by global Leading Companies

- Samsung
- LG
- Sony
- Panasonic
- Sharp
- Walt Disney
- 20th Century Fox
- Warner Brothers
- Netflix
- Dolby Digital
- Direct TV
- Technicolor

• TV makers want to sell more UHD TV
• Studios, looking for more outlets for digital content
Quantum Dot Technology

- Tiny particles, Nano-crystal semiconductors
- Glow when light is shined on them
- Electronic characteristics are closely related to size and shape; size determines color
  - Larger dots emit longer wavelengths (red)
  - Smaller dots emit shorter wavelengths (green)
- Two sizes of dots in these TVs
  - Glow red and green, billions of them in a quantum-dot TV
  - Saturating a sheet of film with a bunch of quantum dots
    - When blue LED shines on the quantum dot-saturated sheet of film, the dots start glowing red and green
    => All three combine to create the ideal white light
- Better Color performance
  - Increased color gamut on LCD screens
  - Improved color accuracy - purer whites, more precise colors
  - Higher peak brightness
  - Higher color saturation

Source: Micron and Industry Analysts
**HDR (High Dynamic Range) Trends**

Netflix announced collaboration with LG, Sony at 2015 CES

- **Anticipating most of original content in HDR by end of 2015**
- **Working with UHD Alliance**: HDR into the 'Ultra HD' standard,
- **Working with film producers to make video in 4K HDR**
- **HDR content**: Working on 60 original series in 2015, including *Marco Polo*, a drama series

**HDR Contents Bandwidth**

*HDR contents require about 20-30% more bandwidth than the equivalent resolution*

- 4K normally in 15 Mbps; 4K HDR will require 18 Mbps
- 2K in 5-6 Mbps; 2K HDR will require 8 Mbps

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**HDR source, two data in stream**

- **HDR algorithm, in TV SoC, expand its dynamic range**
- **Split into two streams composing an HDR image**:
  - The 1st: RGB image to LCD
  - The 2nd: Luminance image to LEDs. luminance gray levels on the individual LED
**DTV System Structure**

**Developed by TV Makers**

- **TV Main PCB Board**
  - Tuner
  - TV SoC
  - FRC
  - DRAM
  - EMMC

- **Front or Side A/V Interface PCB Board**
- **User Interface PCB Board**
- **Power Supplier PCB Board**

- **LVDS Vx1**

**Developed by Panel Makers**

- **TCON PCB Board**
  - DRAM
  - FRC
  - LVDS Vx1
  - TCON

  - **FRC location**
    1. **TV Main PCB Board** (Stand alone or embedded in TV SoC)
    2. **TICON PCB Board** (Stand alone or embedded in TICON)

**Timing Control IC and Panel**

- **Display Timing Control**
- **Column Driver**
  - 1
  - 2
  - ...
  - 1+m

- **Row Driver**
  - 1
  - ...
  - 1+n
  - LCD Panel

**AC Power**

- **Remote Control**
- **Power On/Off**
- **Volume/CH Up/Down**
- **A/V Input/Output**

**User Interface**
Frame Rate Converter (FRC)

FRC (Frame Rate Converter)
- 30/60 FPS → 120 FPS, → 240 FPS
- Motion estimation/compensation
- Super resolution
- Picture quality improvement: contrast, color, sharpness, gamma

FRC is driving more DRAM bandwidth increase because
- Panel is moving to 120 FPS, 240FPS
  - Video processor needs to make more fake frame
  - Image quality needs compensating
  - Processor need more processing power, more memory bandwidth

Source: Micron and Industry Analysts
DTV SoC (System On Chip) Architecture

- Composed of mainly:
  Decoder, video processor, CPU, GPU, memory controller, Interface (transmitter, receiver)

Source: Micron and Industry Analysts
www.arm.com; androidforums.com; www.eetimes.com
2016 High-end 4K TV Platform

<table>
<thead>
<tr>
<th>4K Decoder</th>
</tr>
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<tbody>
<tr>
<td>• 3x 1Gb DDR3 (x16) 1866/2133MT/s</td>
</tr>
<tr>
<td>• 4x 4Gb DDR3 (x16) 1866/2133MT/s</td>
</tr>
<tr>
<td>• xMb SNOR (faster, reliable boot-up)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Main TV Processor</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4x 4Gb DDR3 (x16) 1866/2133MT/s</td>
</tr>
<tr>
<td>• ~16Gb, 17GB/s</td>
</tr>
<tr>
<td>• xMb SNOR (faster, reliable boot-up)</td>
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<table>
<thead>
<tr>
<th>FRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 4x 1Gb DDR3 (x16) 1866/2133MT/s</td>
</tr>
<tr>
<td>• ~4Gb, 17GB/s</td>
</tr>
<tr>
<td>• 64Mb~128Mb SNOR (faster, reliable boot-up)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TICON</th>
</tr>
</thead>
<tbody>
<tr>
<td>• TICON for high-end TV, has embedded DRAM (for frame buffer)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel</th>
</tr>
</thead>
<tbody>
<tr>
<td>• LCD with LED</td>
</tr>
<tr>
<td>• OLED</td>
</tr>
<tr>
<td>• Quantum Dot</td>
</tr>
<tr>
<td>• 120 FPS</td>
</tr>
</tbody>
</table>

Source: Micron and Industry Analysts
DRAM Usage in Video Processing

Video Streaming Source Flow (Through Internet)
- **Compressed source**: To DRAM (streaming buffer) through transport
- **4K Source**: Need 2 times bigger streaming buffer size than FHD source because 4 times video data than FHD, but only 50% compressing efficiency
- **4K Source**: Need broader Internet speed (bandwidth); for instance, Netflix recommends 25 Mbps (5 Mbps for HD)

<table>
<thead>
<tr>
<th>Source</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micron and Industry Analysts</td>
<td><a href="https://www.socionext.com">https://www.socionext.com</a></td>
</tr>
</tbody>
</table>

### Video Decoding and Processing Flow
- **Uncompress and decode**: Video data from Video decoder to DRAM (uncompressed video frame buffer)
- **4K Source** needs 4 times bigger video frame buffer size than FHD source
- **4K Video Decoding** needs 2 times bigger memory bandwidth than HD
- **Video processing** (including FRC) between DRAM and video processor: Uncompressed video data

- De-Interlacing, motion compensation
- Frame rate conversion, up-scaling, down-scaling
- 3D video processing, 2D → 3D conversion
- Picture and picture (double screen)
- Internet, web browsing, multi-format media decoding (3D & enhanced graphic engine for web browsing/gaming)

### DRAM Usage Model Example

#### Key Functions Consuming DRAM
- Firmware (video and audio)
- Transport
- Compressed data buffers
- Compressed video decoding
- Video processing (capturing, scaling, image processing, playback)
- Graphics
- Dual -> Quad -> Octal Core CPU

#### High Frame Rate and FRC
- Panel is moving to 120 FPS, 240FPS; video processor needs to make more virtual Frame
- To compensate image quality, DSP needs more processing power, more memory bandwidth

### Video Decoding and Processing Flow
- Uncompress and decode
- Transport
- Video Decoder
- Video Processor

### DRAM
- Compressed Video Buffer
- Uncompressed Video Buffer
- Other Buffer

### Other
- Wi-Fi
- HDMI 2.0
- Ethernet
- Tuner

### Sources
DRAM/DTV SoC Interface Structure

- Buffering compressed video stream before decoding by decoder
  => 4K TV will require 2 times bigger buffering size than 2K (FHD) TV
- Requires uncompressed video buffer for multiple video processing support
  => 4K TV will require 4 times bigger buffering size than 2K (FHD) TV

Source: Micron and Industry Analysts
Major Density and DRAM Bandwidth Consumers

- Compressed Video Decoding - largest memory consumer in system
- Firmware (Video and Audio) – application software
- Transport Block
  - Receives incoming compressed data streams and de-multiplexes the video and audio
- Compressed Data Buffers
  - Simultaneous decodes are supported by the system
- Video Decoding (H.264, H.265, multimedia format)
- Video Processing
  - Capturing, scaling, image processing, playback
- Graphics
  - Height, bit depth (x-bit per pixel), resolution, the number of display layers => directly impact the memory requirements
DRAM Usage in Compressed Video Processing

- Video Streaming Flow (through Internet)
  - Compressed source: flow to buffer in DRAM, through transport block in TV SoC
  - 4K source needs 2 times bigger buffer size than FHD source
    - Why 2 times bigger? Because of 4 times larger video data than FHD, 50% compression efficiency,
  - 4K source needs broader Internet speed (bandwidth)
    - Netflix recommends 25 Mbpps (vs. 5 Mpps for HD)

Source: Micron and Industry Analysts
DRAM Usage in Uncompressed Video Processing

• Video Decoding and Processing Flow
  ▪ Video decoder sends uncompressed and decoded video stream to DRAM (uncompressed video buffer)
    ▪ 4K source needs 4 times bigger video frame buffer size than FHD source
    ▪ 4K video decoding needs more than 2 times bigger memory bandwidth than HD decoding
  ▪ Uncompressed video processing (including FRC) between DRAM and video processor
    ▪ De-interlacing, MEMC (Motion Estimation & Compensation)
    ▪ FRC (Frame Rate Conversion), Up-Scaling, Down-Scaling, Picture-and-Picture (double screen)
    ▪ 3D video processing, 2D→3D conversion
    ▪ Internet, web browsing, multi-format media decoding
    ▪ 3D and enhanced graphic engine for web browsing/gaming

Source: Micron and Industry Analysts
DRAM Bandwidth Usage Model

Mid-end DTV SoC System Architecture

- Host Processing
  - Application Processor
    - ARM Dual Cortex A9 SMP (Dual NEON)
  - L2 Cache 1MB

- Multimedia & Display
  - GPU ARM Mali400 - 2PP
  - OpenGLES 2.0
  - OpenVG 1.1
  - 2 x 2D Blitter
  - FVDP Display Pipe & 1080p60 Compositor
  - Multi-Format Video Decoder
  - Audio DSP

- Power
  - Low-power Processor
  - Security and DRM Processor

- Peripherals
  - UART, I2C, Smartcard, CI+, GPIO, ...
  - Interfaces
    - 3 x USB2.0
    - 1 x RMII
    - SPI Serial NOR e.MMC
    - LVDS Out
    - 2 x HDMI Rx
    - UCPP WW Demod (with T2/S2)
    - SPDIF Out
    - 3.1125 Out
  - Transport, A/V IO
    - 2 x Serial TS In
    - LVDS Out
    - 2 x HDMI Rx

- DDR3/4L DRAM
  - 64-bit Interface


DRAM bandwidth usage in TV
- Take 60% of total:
  - Decoding
  - Video processing
  - Graphics
  - CPU

Source: Micron and Industry Analysts
### DRAM Market Model

- **Market Size (TAM)**
  - 1.25 B$ (2015) to 2.6 B$ (2020)
  - => ~100% Growth

<table>
<thead>
<tr>
<th>Year</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV Set (M unit)</td>
<td>240</td>
<td>244</td>
<td>252</td>
<td>261</td>
<td>268</td>
<td>275</td>
</tr>
<tr>
<td>Revenue (M)</td>
<td>1,245</td>
<td>1,354</td>
<td>1,597</td>
<td>1,970</td>
<td>2,333</td>
<td>2,633</td>
</tr>
</tbody>
</table>

- **Major TV Customers in 2015**
  - Samsung, LG, Sony take over 50% share of total DRAM TAM

- **24% high-end TVs (mostly 4KTV) drives 50% of DTV DRAM TAM in 2018**

- **2GB/set in 2018**
  - Mixed between low-, mid-, high-end TVs

Source: Micron Market Model 2015