TV SoC Solutions for the Immersive Display & Intelligent Platform

Sep 18, 2017
SJ Choi
System IC Center
LG Electronics Inc
Contents

1. TV Overview
2. Human Visual System
3. TV Technology Trends
4. TV SoC Overview
5. LG TV SoC
6. Tomorrow’s TV
Digital Convergence & Mobile/TV

Personal Electronics
Convergence into Cellular

Home Electronics
Convergence into DTV

1) PVR: Personal Video Recorder

ISOCC’06 Keynote
Digital Convergence & Mobile/TV

Mobile as Convergence Device
- Combine All Functionalities

TV as Entertainment Device
- Immersive Display with Premium Contents

Social
Finance
Traffic
Travel
Game
Health

Media
Shopping
TV Overview

- High-Definition TV
- 16:9 Aspect Ratio
- 3DTV (w/t Glasses)
- UHD TV
- Black and White TV
- Color TV

Past and Future

- Future Technology
  - Wall Paper TV
  - Rollable TV
  - Hologram TV

- Immersive TV
  - 3DTV (w/t Glasses)
  - UHD TV

- Smart TV
  - Streaming
  - Premium Contents

- Digital TV
  - High-Definition TV
  - 16:9 Aspect Ratio

- Analog TV
  - Black and White TV
  - Color TV
TV Overview

- **FHD 120Hz TV** (Frame Rate Conversion, 60 → 120Hz)
- **LED TV** (LED Back-light Control, Local Dimming)
- **Smart TV** (Streaming & App, Computing Core)

TV Evolution

- **UHD TV** (Super Resolution, HD → UHD)
- **HDR TV** (High Dynamic Range, SDR → HDR)
- **OLED TV** (Perfect Black, Color)
TV Overview

TV Reflects the Characteristics of the Human Visual System

Human Vision (Eyes + Brain)

- Left
- Right
- ~65mm

TV & Human Factor

- **Black & White TV**
  - [Human] Sensitive more to Luminance
  - Rod Cell, Cone Cell

- **Digital TV**
  - [Human] 16:9 Aspect Ratio is more Natural
  - 4:3 → 16:9

- **Immersive TV (UHDTV)**
  - [Human] Wider View Angle → More Immersive

- **Immersive TV (3DTV)**
  - [Human] 3D Depth
TV Overview

TV Display → Higher Contrast and Wider Color Representation

◆ Bartleson-Breneman Effect
  ▪ [Human]
    Higher Contrast → Perceived Picture Brighter

◆ Helmholtz-Kohlrausch Effect
  ▪ [Human]
    Wider Color Gamut → Perceived Picture Brighter
TV Overview

OLED: Ultimate Display Technology with Excellent Picture Quality

Advantages of OLED TV

◆ Simple Structure
  ▪ Self-emissive (no BLU\(^1\))
  ▪ Pixel Unit = Lighting Unit

◆ Ultimate Picture Quality
  ▪ Real Black: Ultimate Contrast Ratio
  ▪ Wide Color Gamut

◆ Innovative Form-Factor
  ▪ Paper-slim Depth (~4mm)
  ▪ Light Weight
  ▪ Curved & Flexible Display
  ▪ Wall Paper Display

1) BLU: Back-Light Unit
TV Overview

LG OLED: White-OLED (Tandem) + Color Filter (RGBW)

RGB OLED (Conventional)

- Color Sub-pixel: RGB-OLED
- Issues: Productivity
  - Difficult Commercialization

W-OLED + Color Filter (LG)

- Color Sub-pixel: W-OLED + Color Filter
  - Color Filter: White + RGB
  - Tandem W-OLED (Multi-layer)
    → Improve Luminance
- TFT: Oxide TFT
TV Overview

**UHD TV**

**Super Real**

◆ Detail with More Number of Pixels

Low Resolution

High Resolution

**ABCD**

**Immersive**

◆ Immersive with Larger Screen Size

* Japan NHK Research

<table>
<thead>
<tr>
<th></th>
<th>FHD (1,920x1,080)</th>
<th>UHD_4K (3,840x2,160)</th>
<th>UHD_8K (7,680x4,320)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Size</td>
<td>55”</td>
<td>84”</td>
<td></td>
</tr>
<tr>
<td>View Angle</td>
<td>30°</td>
<td>60°</td>
<td>100°</td>
</tr>
<tr>
<td>View Distance</td>
<td>3H: ~2M</td>
<td>1.5H: ~1.5M</td>
<td>0.75H: ~</td>
</tr>
</tbody>
</table>

55” TV: D(~140cm), H(68.5cm), 3H(~2M)
84” TV: D(~213cm), H(104cm), 1.5H(1.5M)
System IC

System IC Plays a Crucial Role for the Success of System

- System S/W
  - Platform
  - BSP\(^1\)
  - Service/Contents
  - HW/SW Optimization

- TV System Design
  - Architecture Design
  - SoC Platform Design
  - Global Broadcasting Technology
  - Picture Engine
  - Multimedia Service

- Design Infra
  - Foundry
  - Design Methodology
  - Physical Design
  - Low Power Design

\(^1\) BSP: Board Support Package
System IC

Market-leading Set Maker develops its own SoC and Platform

Overview

60s-70s IDM
80s-00s Fabless & Foundry
2010+ Market-leading Set Maker

Past

TV

Smart Phone

Now

Set Maker
Fabless
Set Maker
Fabless
TV SoC

Connectivity
- HDMI
- USB
- Analog A/V

TV SoC
- Connectivity
- Sound
- Demodulator
- Picture Engine
- CPU & Peripheral
- GPU
- Memory Controller

Memory
- DDR
- eMMC

TV Panel
- LCD
- OLED

Remote Controller
User Experience

Immersive Picture

Contents
- Smart Feature
  - TV Basic
    - RF
      - Terrestrial
      - Cable/Satellite
  - Streaming
  - App Service
- TV Panel

Immersive Picture

Overview

Trends

- Full HD → Ultra HD
  - UHD Contents
  - Broadcasting Technology
  - UHD Display
  - LCD → OLED Technology
  - HDR Technology

- TV Platform
  - IP Delivery: TV → Mobile/Tablet
  - Contents Delivery: Netflix, Amazon
  - User Experiences: webOS, Tizen, Android

- Competitions
  - Japan vs Korea
  - Korea vs China/Taiwan
  - Apple/Google
Computing Unit
- CPU: ARM Cortex-A72/57
- GPU: ARM Mali
- DSP
- Neural Engine (in Future)

Broadcasting & Multimedia
- Global Demodulator: ATSC/DVB/ISDB-T/DTMB

Sound & Picture Engine
- Audio Codec & Processing
- Immersive Picture Engine
- Display Panel Interface

Connectivity & Mixed IP
- DDR3/4
- HDMI2.0
- USB3.0/eMMC5.1
- Ethernet
- ADC/DAC/PLL
<table>
<thead>
<tr>
<th>High-end TV SoC (UHD)</th>
<th>`11</th>
<th>`12</th>
<th>`13</th>
<th>`14</th>
<th>`15</th>
<th>`16</th>
<th>`17</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>H15</td>
<td>H15+</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1st UHD SoC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-end TV SoC (FHD)</td>
<td>L9</td>
<td>H13</td>
<td>H14</td>
<td></td>
<td></td>
<td>M16</td>
<td>M16+</td>
</tr>
<tr>
<td></td>
<td>1st DTV SoC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>webOS Platform</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stand-Alone</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>FRC</td>
<td>3D Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process</td>
<td>40nm</td>
<td></td>
<td></td>
<td>28nm</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1) Super Resolution (FHD → UHD High-Quality Conversion), 2) High Efficiency Video Coding
**TV SoC**

- **Process**: TSMC 28nm (T28HPC+, 0.9V/2.5V)
- **Package**: 27x27 mm² fcBGA

**CPU**
- ARM Cortex A53 1.15GHz (x4, OD:0.95)
- NEON, Trustzone
- L1S 32KB/32KB, L2S 1MB

**GPU/GFX**
- ARM MALI T820MP2@ 650MHz
- OpenGL ES 1.1/2.0/3.0/3.1
- OpenCL 1.2 full profile, DirectX 11.1
- Renderscript for Google TV
- Vivante GC520@300MHz Graphic Engine
- DirectFB, AFBC

**MFD** (G1 Decoder)
- FHD 30fps(x2) or FHD 60fps
- VP8(1080p)
- H.264-MVC Stereo High FHD (4K 30fps)
- H.264 BP/MP & HP@L4.2
- VC-1 SP/MP & AP@L3
- MPEG-2 MP@HL & MPEG-4 SP/ASP
- DivX 3~6, H.263 P0/P3
- RV 8/9/10, AVS/AVS+ Guardian@L6.2
- Sorenson Spark@L70
- MJPEG Baseline, JPEG

**G2 Decoder**
- 4K 10bit VP9 Decoder (60 fps)

**HEVC Decoder**
- 4K 10bit HEVC Decoder (120 fps)

**ATSC 3.0 Support**
- ATSC 3.0 TP
- 4K SHVC Decoder (60 fps)

**Encoder**
- H.264(VP8) 1080p@30fps MP@L5.1

**Audio/Sound DSP**
- HiFi EP Dual@600MHz, cache 32KB/32KB
- DRA, Ogg Vorbis
- DTS-M6n
- DD, DD+, MP2, MP3, ADPCM, LDPCM,
- AAC, HE-AAC, HE-AAC v2
- WMA9(standard)/10(pro)/loseless, DDCO
- HE-AAC/DD+ to DD
- G.711, G.729
- AC-4, MPEG-H, ATMOS

**Picture Quality**
- 4K MEMC 120Hz.
- HDR (Dolby, HLG, Technicolor)
- 2Dto3D
- Enhance SR
- LED Local Dimming(HDR)
- Wide Gamut

**Security Engine**
- OTP, 3DES, AES, RSA, SHA, C2/CSA
- Multi2, DVB-CSA
- Trustzone
- MD5, SHA-224
- Secure Random Number Gen.
- RSA 2048bit

**Demodulator**
- VSB/QAM,DVB-T/C, ISDB-T
- Analog Demod

**Memory**
- Unified memory architecture
- Up to DDR3/4 2133MHz 32x2
- eMMC5.01

**Interface**
- Ethernet 100 Mbps Phy
- Ethernet 100/1000Mbps MAC
- USB2.0 x3, USB3.0 x1
- HDMI 2.0b Rx, x4
- PWMx3, 12Cx6, UARTx2

**Display Engine**
- HDR, SR
- 2Dto3D, Local/D
- HDMI Rx. x4
- 2D Gfx: Vivnate520

**Security Engine**
- OTP, 3DES, AES, RSA, SHA, C2/CSA
- Multi2, DVB-CSA
- Trustzone
- MD5, SHA-224
- Secure Random Number Gen.
- RSA 2048bit

**Memory**
- Unified memory architecture
- Up to DDR3/4 2133MHz 32x2
- eMMC5.01

**Audio/Sound DSP**
- HiFi EP Dual@600MHz, cache 32KB/32KB
- DRA, Ogg Vorbis
- DTS-M6n
- DD, DD+, MP2, MP3, ADPCM, LDPCM,
- AAC, HE-AAC, HE-AAC v2
- WMA9(standard)/10(pro)/loseless, DDCO
- HE-AAC/DD+ to DD
- G.711, G.729
- AC-4, MPEG-H, ATMOS

**Picture Quality**
- 4K MEMC 120Hz.
- HDR (Dolby, HLG, Technicolor)
- 2Dto3D
- Enhance SR
- LED Local Dimming(HDR)
- Wide Gamut

**Security Engine**
- OTP, 3DES, AES, RSA, SHA, C2/CSA
- Multi2, DVB-CSA
- Trustzone
- MD5, SHA-224
- Secure Random Number Gen.
- RSA 2048bit

**Demodulator**
- VSB/QAM,DVB-T/C, ISDB-T
- Analog Demod

**Memory**
- Unified memory architecture
- Up to DDR3/4 2133MHz 32x2
- eMMC5.01
**TV SoC**

**Memory Bandwidth**

**Technical Issues**

- **Total Memory Bandwidth**
  - Full HD ➔ Ultra HD
  - DDR Clock: 800MHz ➔ 933 ➔ 1,066 ➔
  - Bus Width: 16x4 (64bit) or 16x6 (96bit)

- **Frame Buffer Compression**
  - GPU: AFBC (ARM Frame Buffer Compression)
  - Visually Lossless: 20/40/50%

- **Real-time Constraints (QoS)**
  - Real-time: Picture Engine, Display
  - Local Buffer
  - Scheduling

- **Smart Memory Balancing**
  - Video Encoder/Decoder
  - CPU/GPU

- **CPU/GPU Performance**
  - Dedicated CPU/GPU Bus
TV SoC

TV Picture Engine

- **Picture Quality: TV Panel + Picture Engine**
  - TV Panel: LCD/OLED

- **Contrast and Color (TV Panel)**
  - Contrast: Dynamic Range
  - Color: Gamut
  - Resolution: 4K, 8K

- **Noise and Sharpness (Picture Engine)**
  - Noise Reduction: Analog, MPEG
  - Sharpness: Edge, Texture

- **Format Conversion (Picture Engine)**
  - Up/down Resolution Scaling
  - De-interlacing: Interlaced → Progressive

- **Panel Characteristics**
  - LCD Motion Blur: FRC 24/30/60 → 120Hz

![Diagram of Picture Engine](image)
TV SoC

Home Entertainment Center & Personalized Screen

◆ Competitions
  ▪ Display: TV Set Makers
  ▪ TV and Mobile Platform
  ▪ Content Service

◆ Immersive TV Screen
  ▪ Vivid and High Picture Quality
  ▪ Immersive Ultra HD Screen
  ▪ Feeling of “Being There”

◆ Contents & User Experiences
  ▪ Premium Contents
  ▪ Contents Recommendation
  ▪ Personalized Screen (News/Advertisement)
TV SoC

**Intelligent Platform: Picture Engine**

- **Prevalence of Deep Learning**
  - Big Data
  - Computing Power
  - Learning Skill

Alexnet: ’12 ILSVRC (Image Classification Challenge) Winner

EDSR: ’17 NTIRE_SR (Super Resolution Challenge) Winner

- **Picture Quality**
  - Pixel Improvement: Super Resolution, Noise Reduction
  - Object-Centric Processing: Object Detection
  - Picture Generation: Frame Rate Conversion

- **Intelligent Picture Quality Tuning**
  - Input Analysis & Optimal Picture Tuning
  - Watching & Learning

![Diagram of TV SoC and Picture Engine](image)

Input

TV

Picture Engine

High Quality Picture

Self Learning

DNN

Input Analysis

[Diagram showing the flow of input through TV SoC and Picture Engine]