Driving the new era of immersive experiences
Immersive experiences
The experiences worth having, remembering, and reliving

Draw you in... Take you to another place... Keep you present in the moment...
Immersion enhances everyday experiences

Experiences become more realistic, engaging, and satisfying

Spanning devices at home, work, and throughout life

- Theater-quality movies and live sports
- Realistic gaming experiences
- Life-like video conferencing
- Smooth, interactive, cognitive user interfaces
- Augmented reality-based experiences
- New virtual reality applications
- Theatrical-quality movies and live sports
Driving the new era of immersive experiences
Focusing on broader dimensions

- **Visual quality**
  - Pixel quantity
    - Resolution and frame rate
  - Color accuracy, contrast, and brightness

- **Sound quality**
  - High resolution audio
    - Sampling rate and precision
  - Sound integrity
    - 3D surround sound and clarity

- **Intuitive interactions**
  - Natural user interfaces
    - Responsive, accurate, and seamless
  - Contextual interactions
    - Intelligent and personalized
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Visual quality is much more than resolution and frame rate. Color accuracy, contrast, and brightness are also critical elements.

**Pixel quantity**

**Resolution**
Increased definition and sharpness

**Frame rate**
Reduced blurring and latency

**Pixel quality**

**Color accuracy**
More realistic colors through an expanded color gamut, depth, and temperature

**Contrast and brightness**
Increased detail through a larger dynamic range and lighting enhancements
Taking an end-to-end approach to improve visual quality
The journey of light from the mobile camera to a correct pixel on the display is challenging

End-to-end solutions
Color management, artifact removal, optimized click-to-shoot time

Component tuning | Image processing | System optimization
A heterogeneous computing approach is needed
Specialized engines to meet visual processing requirements at low power and thermals

- **Camera image capture**
  - Lens correction, noise removal, and 3A

- **Image processing**
  - Color correction, tone mapping, and computational photography

- **Video compression**
  - Video encode and decode

- **High-end gaming**
  - Rendering, tessellation, and geometry shading

- **Display image**
  - Compositing, gamut mapping, and calibration to displays

* Not to scale
Cognitive technologies are making visuals more immersive

Using computer vision and machine learning to capture and playback better pixels

**Scene understanding**
- Recognize the objects, people, and the overall scene

**Automatic configuration**
- Adjust camera settings
- Track, zoom, and focus on objects of interest

**Relive your moments**
- Pixels adjust to user preferences and environment for best viewing experience
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- **High resolution audio**
  - Sampling rate and precision

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Enriching sound by focusing on broader dimensions
Providing truly immersive audio experiences optimized for how humans hear

High resolution audio

Sampling rate
Increased sampling rates to match human hearing

Precision
Increased bits-per-sample for increased audio fidelity

Sound integrity

3D surround sound
Accurate 3D capture and playback of audio

Clear audio
Zoom and focus on the important sound while filtering out the noise
Using multiple dimensions to capture vivid 3D sound

Understand environment
Automatically adjust settings based on environment detection and voice identification

Isolate sounds of interest
Zoom, focus, and track the sounds of interest while separating out other sounds

Capture realistic sound
Capture high-resolution, 3D surround sound through object-based or scene-based audio

Object-based sound capture
Scene-based sound capture
Immersive audio playback for realistic 3D surround sound

Speaker virtualization for 3D surround sound

Facial recognition and head tracking for dynamic sweet spot
Optimizing sound quality across the system
The journey of audio from the microphone to the speaker is challenging

Mic
Size, cost, and placement constraints result in:
• Limited number of mics
• Increased noise

SoC
Addresses mic and speaker challenges while enhancing audio

Speaker
Size and cost constraints result in:
• Limited number of speakers
• Reduced quality and fidelity

End-to-end solutions
High-res audio, noise suppression, and 3D surround sound

Component tuning  |  Audio processing  |  System optimization
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- **Contextual interactions**
  - Intelligent and personalized
Intuitive interactions immerse us in the moment

Natural user interfaces
- Seamless
- Responsive
- Accurate

Providing the appropriate interfaces based on the user, device, and application

Contextual interactions
- Intelligent
- Personalized

Providing the right level of immersion based on context
Natural user interfaces for intuitive interactions

**Motion & gesture recognition**
Use computer vision, motion sensors, or touch

**Voice recognition**
Use natural language processing

**Face recognition**
Use computer vision to recognize facial expressions

**Eye tracking**
Use computer vision to measure point of gaze

**Personalized interfaces**
Learn and know user preferences based on machine learning

**Bringing life to objects**
Efficient user interfaces for IoT

Adaptive, multimodal, user interfaces
Providing the right level of immersion based on context

Tursting your device to take appropriate actions

**Contextual awareness**
- Scene recognition
- Sensor fusion
- Proximal discovery
- Learned preferences

**Intelligent notifications**
- The right information at the right time
- Appropriately interrupted immersion

**Personalized experiences**
- Reduced friction
- Customized for the user
Making virtual reality truly immersive

Through increased visual quality, enhanced sound quality, and more intuitive interactions
Virtual reality is the ultimate level of immersion

- Visuals so vibrant that they are indistinguishable from the real world
- Sound so accurate that it is true to life
- Interactions so intuitive that you forget there is even an interface
Immersive virtual reality has extreme requirements

- Extreme pixel quantity and quality: Screen is very close to the eyes
- Broad field of view: Humans have a 180 degree field of view
- Stereoscopic display: Humans see in 3D
- Minimal latency: Minimized system latency to remove perceptible lag
- Natural user interfaces: Seamlessly interact with VR using natural movements, free from wires
- Visual quality
- Sound quality
- Intuitive interactions
- Immersion
- High resolution audio: Up to human hearing capabilities
- 3D surround sound: Realistic 3D positional audio that is accurate to the real world
- Precise motion tracking: Accurate on-device motion tracking
An end-to-end approach is required for virtual reality

Optimizing for motion to display latency

- **Motion detection**
  Gyro, accelerometer, camera, or other sensors detect movement

- **Visual processing**
  Calculate movement and create appropriate image through multi-stage visual processing

- **Screen update**
  Immediately update display with image to minimize latency

End-to-end approach
A heterogeneous computing approach is needed for VR
Specialized engines to meet processing requirements at low power and thermals

Virtual reality
Computer vision, image processing, sensor processing, graphics, video processing, location, and cloud interaction

<table>
<thead>
<tr>
<th>Location</th>
<th>CPUs</th>
</tr>
</thead>
<tbody>
<tr>
<td>GPU</td>
<td>Memory subsystem</td>
</tr>
<tr>
<td>Display engine</td>
<td>Video engine</td>
</tr>
<tr>
<td>Camera ISP</td>
<td>Modem</td>
</tr>
<tr>
<td>DSP (audio, sensor, &amp; camera co-processor)</td>
<td></td>
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</tbody>
</table>

High-utilization

* Not to scale

Entire SoC is used!
Qualcomm Technologies, Inc. (QTI) is uniquely positioned

To deliver efficient, comprehensive solutions for immersive experiences
QTI is uniquely positioned to deliver superior immersive experiences

Providing efficient, comprehensive solutions

**Immersive experiences**
- Visual quality
  - Consistent, accurate color
  - In-focus images
  - Low-light video & photography
- Sound quality
  - 3D surround sound
  - Noise removal
  - Dynamic sweet spot
- Intuitive interactions
  - Seamless, responsive, smooth user interfaces
  - Intelligent, contextual interactions

**Within device constraints**
- Development time / Sleek form factor / Power and thermal efficiency / Cost

**Commercialization**
- Via Snapdragon™ solutions
  - Via ecosystem enablement
- Via ecosystem enablement
  - Custom designed processing engines
  - Comprehensive solutions across tiers
  - Snapdragon development platforms
  - App developer tools
  - Ecosystem collaboration

Snapdragon is a product of Qualcomm Technologies, Inc.
Using an efficient heterogeneous computing solution
Specialized engines to meet processing requirements at low power and thermals

- Superior performance per mW
- GPU compute for image processing
- Graphics rendering with HW tessellation

- TruPalette™ color enhancement
- ecoPix™ power savings
- Composition

- 14-bit twin ISP
- Ultra-fast laser & phase detect autofocus
- Triple noise reduction: Bayer, wavelet, and temporal
- Dual camera support for depth, sensor fusion, and ultra low light

- High bandwidth at low power and latency
- Multiple radio technologies and bands

Some features are only available on specific Snapdragon processors. Consult processor specifications for feature availability. TruPalette, ecoPix, Adreno, Spectra, Kryo, Krait, Fluence, and Hexagon are products of QTI.
Offering superior development and optimization tools

Enabling content creation and tuned devices

**Content creation tools**

- Specialized solutions for development
  - Adreno SDK
  - Vuforia™ SDK
  - Hexagon SDK
- Debugger for solving
  - Snapdragon Debugger
- Profiler for optimization
  - Snapdragon Profiler
- Third-party middleware support
  - Unity & Epic Unreal Engine

**Device optimization tools**

- Calibration and tuning
  - Chromatix™ color optimization tool
  - Qualcomm Display Color Management
  - Qualcomm Audio Calibration Tool
- Analysis and debugging
  - Qualcomm Commercial Analysis Toolkit
  - Qualcomm eXtensible Diagnostic Monitor

**Other ecosystem enablement**

- Development devices
  - Mobile Development Platform
  - DragonBoard™
- Customer support
  - Customer engineers

Vuforia and Chromatix are products of QTI. DragonBoard is distributed by Intrinsyc.
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- **Contextual interactions**
  - Intuitive interactions
    - Cognitive technologies

End-to-end solutions

Heterogeneous computing
Thank you

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