IoT Value Chain

Audio/Voice

Voice Communication
Voice Pre-Processing
Low Power Audio
Audio Post Processing

Always-on UI

Voice Activation
Face Trigger
Gesture Trigger
N-axis
Sound Sensing

Sensing

Connectivity

BT
Wi-Fi
Zigbee
Weightless
Wearables: Main Design Considerations

Implementation Constraints

► Power Consumption
  ► Battery size and weight limitation
  ► Less frequent/limited charging
    (e.g. sleep tracker)
  ► Always-on UI, always-connected

► Form Factor
  ► Highly integrated solution

► Cost Sensitive
  ► Fewer IPs and smaller die size

Feature Set Considerations

► User Interface
  ► Limited display/touch-screen (if any)
  ► Always-on voice/gesture control
    (primary UI in Android Wear)

► Connectivity
  ► Bluetooth Low Energy (BLE) for
    sensor and app data communication
  ► A2DP and Hands-Free BT profiles
    for audio playback and voice calls

Sensor Fusion, Contextual Awareness

Ultra-low power, single-core solution for:
Connectivity, Audio, Voice and Sensor Fusion
Power Challenge for Wearables

Under “normal usage”, most of the power is consumed during screen-off use-cases, running:

1. BLE
2. Sensor fusion
3. Always-listening (voice)
4. Always-watching (face, gesture)
5. Audio playback

<table>
<thead>
<tr>
<th>Application</th>
<th>Standard Application Processor</th>
<th>Moto X (Using TI C55 DSP)</th>
<th>Acceptable for a Smartwatch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice Activation</td>
<td>~20mA</td>
<td>4.5mA</td>
<td>0.6mA</td>
</tr>
<tr>
<td>Wake-on-gesture, wake-on-face</td>
<td>~40mA</td>
<td>N/A</td>
<td>1.1mA</td>
</tr>
<tr>
<td>BLE (including RF)</td>
<td>Negligible</td>
<td>N/A</td>
<td>0.03mA</td>
</tr>
<tr>
<td>Smartwatch always-on battery life (voice + gesture + face + BLE)*</td>
<td>5 hours</td>
<td>67 hours = ~3 days (voice only)</td>
<td>173 hours = ~7 days</td>
</tr>
</tbody>
</table>

*Assuming 300mAh battery

How do we get here?

Must use an application-specific processor, integrating multiple functions
Solution Overview

- A complete solution based on a single TeakLite-4 DSP, handling Audio/Voice, Sensor Fusion, always-on UI and Connectivity
  - **Feature rich**: Supporting various connectivity standards, audio/voice functions, always-on UI and sensor fusion
  - **Smallest die size**: Single core replacing at least 2 cores in alternative solutions
  - **Ultra-low power consumption**: HW platform including DSP well tuned for such applications
  - **Integrated and pre-verified**: HW platform and SW solution

- **Serving several key markets**
  - Wearable devices
  - Wireless audio (speakers and headsets)
  - Smart home
  - Future user-centric IoT devices
Covers all Bluetooth, Audio/Voice and Sensor Fusion functionalities

- Down to 150Kgates for the entire integrated HW platform

- Ultra-low power consumption
  - <150uW @ 28nm (always-on voice and face triggers + sensor fusion + BLE)
  - PSU 2.0 - latest generation power scaling technology
  - Power-optimized 32-bit DSP for control + audio/voice processing
  - Power-tuned CEVA-Bluetooth IP
  - Single core eliminates IPC overhead

- CEVA-TeakLite-4 handles multiple pre-integrated SW modules
  - Complete Bluetooth stack
  - Always-on functionality e.g. voice trigger, face trigger
  - HD audio and voice processing
  - Audio/Voice pre/post-processing
  - Sensor fusion (context awareness)
  - Android Framework (incl. KitKat)
  - RTOS, libraries

- Plenty of headroom for customer’s proprietary software
Solution Diagram

Software IP
- Bluetooth Profiles
- Audio/Voice Codecs
- Sensor Fusion
- Voice Pre-Processing
- Voice Triggering
- Audio Post-Processing
- Face Triggering

Software Framework
- DSP Library
- Audio/Voice Library
- Android Framework (AMF)
- C Run-time Library
- Bluetooth Controller
- RTOS

Hardware Platform
- CEVA-Bluetooth
- CEVA-TeakLite-4 DSP
- System I/Fs and Peripherals

Real-time Emulation Platform
- Radio
- CODEC
- sensors
CEVA-TeakLite-4 Based Bluetooth

- **CEVA-Bluetooth**
  - Classic Bluetooth (2.1+EDR, 3.0)
  - Low Energy Bluetooth (4.0/4.1) Single/Dual Mode
  - CEVA-Bluetooth BB HW integrated with TL4
  - CEVA-Bluetooth Controller SW stack running on TL4
  - BlueRF for 3rd party Radio

- **Single Mode**
  - Reduced HW/SW footprint for low power & silicon cost
  - CEVA-Bluetooth host SW stack and profile services running on TL4
  - API to licensee’s SW stack

- **Dual Mode**
  - Addition of Low Energy protocol HW & SW to Classic BT
  - CEVA’s partners host SW stack and profiles
  - HCI for 3rd party host software
Leveraging CEVA-TeakLite-4 V2 (*)

► New instructions and interfaces
  ► For wireless standards implementation
  ► For audio/voice processing

► 30% code size reduction
  ► Optimized instruction encoding
  ► Reduced memory silicon area
  ► Reduced power
  ► Improved P$ utilization and cycle count

► 20% power reduction
  ► Improved granularity of Power Scaling Unit (PSU)

(*) Compared to V1
Enhanced Power Scaling Unit

► Multiple clock sources
  ► DSP Core - internal unit manages the clock automatically
    ▶ Early in instruction decode pipe stage
    ▶ Unneeded modules are shut down
  ► Memory subsystem
  ► Data & program memories
  ► Emulation & debug modules

► Multiple voltage domains
  ► DSP and memory subsystem
  ► Data and Program L1 memories - enables data retention when core is powered off
  ► Emulation & debug modules

Improved Granularity Enables Ultra-Low Power Controlled Both Automatically and by Software
Always-on Triggers and Sensor Fusion

► **Always listening microphone**
  ► Voice trigger/command, speaker verification
  ► <20uW @ 28nm

► **Always watching camera**
  ► Face wake-up, gesture, gaze detection

► **Contextual awareness**
  ► Multi-sensor processing (Accelerometer, Gyroscope, Magnetometer, Barometer, Humidity, Light, Heart Rate...)

► **Bluetooth Low-Energy (BLE)**
  ► Connectivity and Beacons
Voice and Audio Pre/Post-Processing

Voice Pre-Processing
- Alango Voice Capture
  - AEC
  - NR
  - AGC
  - DRC
  - Dual mic
- Other 3rd party solutions also available

Audio Post-Processing
- Dirac Power Sound
  - Enhanced sound from small speakers
  - Pure and loud sound
  - Maximum bass without distortion
  - Resonances are wiped out
- Other 3rd party solutions also available
Wearable Device Requirements

- Low power audio processing
  - Audio decoding
  - Audio encoding
  - Audio post-processing

- Low power voice processing
  - Vocoder
  - Noise reduction, beam forming

- Ultra low power always-on
  - Always-listening voice trigger
  - Always-watching face trigger

- BLE/BT4.1 Dual Mode (Bluetooth Smart Ready)

- Sensor fusion (context awareness)
## Example Wearable Use Case: Standby

Smartwatch is on Standby: Always-on UI + Sensor Fusion + BLE

<table>
<thead>
<tr>
<th>Function</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BLE</strong></td>
<td></td>
</tr>
<tr>
<td>Baseband HW</td>
<td>CEVA DM Baseband HW</td>
</tr>
<tr>
<td>Controller SW</td>
<td>CEVA DM controller SW</td>
</tr>
<tr>
<td>Host SW</td>
<td>DM Host SW</td>
</tr>
<tr>
<td><strong>Always-Watching Camera</strong></td>
<td></td>
</tr>
<tr>
<td>Face trigger on DSP</td>
<td>Visidon</td>
</tr>
<tr>
<td></td>
<td>Face Unlock</td>
</tr>
<tr>
<td><strong>Always-Listening Microphone</strong></td>
<td></td>
</tr>
<tr>
<td>Voice trigger on DSP</td>
<td>Sensory TrulyHandsfree 3.0</td>
</tr>
<tr>
<td><strong>Contextual awareness</strong></td>
<td></td>
</tr>
<tr>
<td>Sensor Fusion</td>
<td>Accelerometer/Gyroscope/Magnetometer/Barometer/Gesture/Shake</td>
</tr>
</tbody>
</table>

Less than 150uW for Always-on UI + Sensor Fusion + BLE
## Example Wearable Use Cases: Voice Call, Wireless Audio

### Smartwatch Voice Call using Built-in Speakerphone

<table>
<thead>
<tr>
<th>Function</th>
<th>Features</th>
</tr>
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<tbody>
<tr>
<td>Bluetooth V4.0 Classic Mode</td>
<td>Baseband HW</td>
</tr>
<tr>
<td>Controller SW</td>
<td>CEVA DM Ctrl SW</td>
</tr>
<tr>
<td>Host SW (HFP)</td>
<td>DM Host SW</td>
</tr>
<tr>
<td>Voice Processing</td>
<td>mSBC vocoder</td>
</tr>
<tr>
<td>Pre-processing</td>
<td>Alango Voice Capture, AEC (64ms acoustic echo tail), NR, AGC, DRC</td>
</tr>
<tr>
<td>Control</td>
<td>RTOS</td>
</tr>
</tbody>
</table>

### Smartwatch Audio Playback Streamed to BT Headset

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<tr>
<td>Bluetooth V4.0 Classic Mode</td>
<td>Baseband HW</td>
</tr>
<tr>
<td>Controller SW</td>
<td>CEVA DM Ctrl SW</td>
</tr>
<tr>
<td>Host SW (A2DP)</td>
<td>DM Host SW</td>
</tr>
<tr>
<td>Audio Playback</td>
<td>MP3 Decoder</td>
</tr>
<tr>
<td>SBC Encoder</td>
<td>16-48KHz, 96-320Kbps</td>
</tr>
<tr>
<td>Post-processing</td>
<td>Dirac Power Sound</td>
</tr>
<tr>
<td>Always-on Microphone</td>
<td>Voice trigger on DSP</td>
</tr>
<tr>
<td>Control</td>
<td>RTOS</td>
</tr>
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</table>

**Less than 60MHz and 1.6mW**

**Less than 70MHz and 1.9mW**
Wireless Audio Requirements

► Low power audio processing
  ► Audio decoding
  ► Audio post processing

► Low power voice processing (speakerphone)
  ► Vocoder, voice pre processing, echo canceller

► Ultra-low power always-listening voice control

► BT4.1 Dual Mode (Bluetooth Smart Ready)
# Example Wireless Audio Use Case

<table>
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<tr>
<th>Function</th>
<th>Features</th>
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<tbody>
<tr>
<td>Bluetooth Classic</td>
<td></td>
</tr>
<tr>
<td>Baseband HW</td>
<td>CEVA DM BB HW</td>
</tr>
<tr>
<td>Controller SW</td>
<td>CEVA DM Ctrl SW</td>
</tr>
<tr>
<td>Host SW (A2DP)</td>
<td>DM Host SW</td>
</tr>
<tr>
<td>Audio Playback</td>
<td></td>
</tr>
<tr>
<td>SBC decoder</td>
<td>16-48KHz, 96-320Kbps</td>
</tr>
<tr>
<td>Post-processing</td>
<td>Auto Volume, DRC, EQ, Bass/Treble Enhancement, Virtual Surround</td>
</tr>
<tr>
<td>Always-Listening Microphone</td>
<td>Voice trigger on DSP</td>
</tr>
<tr>
<td>Control</td>
<td>RTOS</td>
</tr>
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<td></td>
<td></td>
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Less than 60MHz and 1.6mW
Chip Example: DBMD2 – Cost Effective, Low Power Audio/Voice Processor for Always-on Functions

DSP Group DBMD2 address all key requirements for always-on functions

- Utilizes TeakLite-III DSP to provide sufficient processing power
- Supports different power save modes by turn-off the DSP core and any of the peripherals modules in the chip
- Enables fast TTM - Complete SW development tools including utilization of on-chip profiler and complete software framework
- Small form factor (3mm x 3mm)
- Availability of SW algorithms by DSPG/CEVA/partners
- Supports various always-on functions including:
  - Low power voice trigger wake-up (below 2mW)
  - Low power voice commands
  - Low power sensor–hub functionality

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Summary

► IoT and wearables require new system solutions
  ► Requires much more focus on power consumption and cost
  ► E.g., for a smartwatch to run a week between battery charges, 2mA is the limit for always-on (screen-off) use case

► CEVA’s announced TeakLite-4 based integrated platform delivers:
  ► Connectivity, audio, voice, sensing, always-on UI
  ► <150Kgates, single-core platform including BT baseband HW
  ► <150uW @ 28nm (always-on voice and face triggers + sensor fusion + BLE)
  ► Can scale for advanced screen-on use-cases with other TL4 cores

► CEVA partners offer complementary SW solutions
  ► Audio, voice, imaging, pre/post-processing, BT, GNSS, WiFi
THANK YOU