



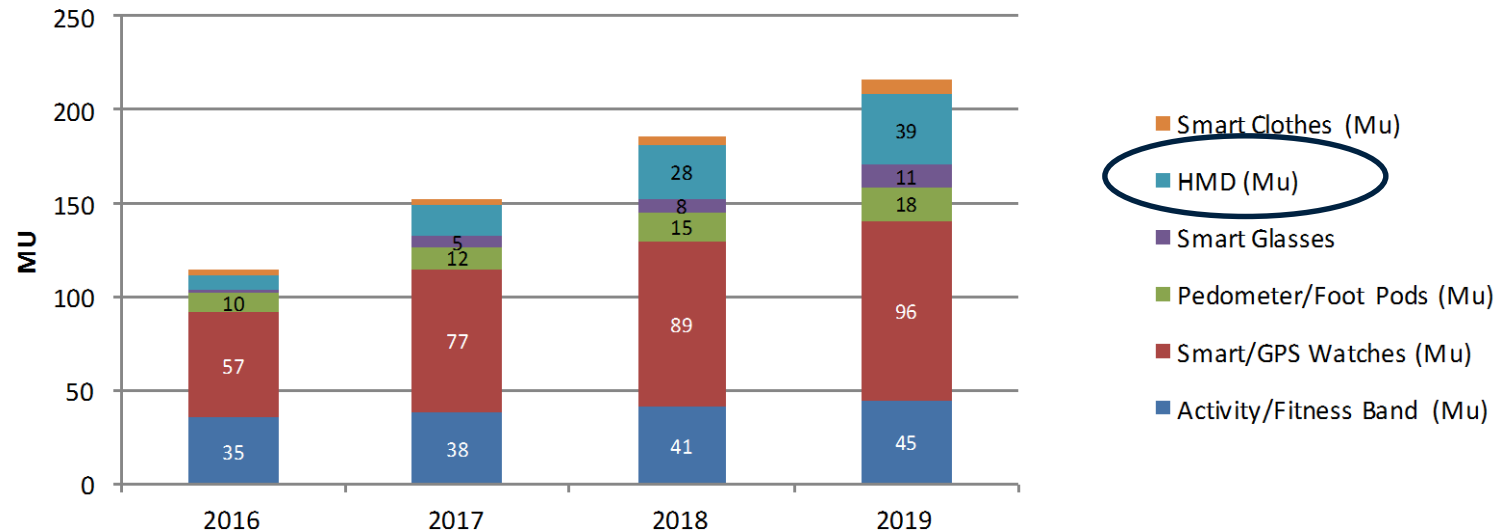
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InvenSense Developers Conference 2016

InvenSense
ICM-30670 SH

Wearable Market Size & Trends

Wearable Market TAM



- **Top 5 OEMs**

- Samsung
- HTC
- Oculus
- Sony
- BaoFeng

- **Key Market Trends**

- Head Mount User Experience
- Remote Control User Experience
- Content Availability

INVN inside HMD/VR/Smart Glasses

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Microsoft HoloLens



Oculus/Facebook



HTV Vive



INVN Delivers the Required Sensor Performance for HMD/VR

Vizux M100



Epson Moverio



ODG M-7



HMD/VR Platforms

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Good Gyro Needed for Pokeman Go

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<http://www.makeuseof.com/tag/you-might-need-upgrade-phone-pokemon-go/>

- “Pokemon Go is finally out. All your friends are playing it, and you want to join in. Unfortunately, your Android phone is letting you down, and it’s making you krabby.”
- **Augmented Reality Requires a Gyroscope”**
- “I downloaded Pokemon Go yesterday, and was positively *gloom-y* to discover that the much-hyped augmented reality (AR) feature wasn’t available on my device. When I activated it, an error message popped up that said, “We’re not detecting your phone’s orientation. Would you like to turn off AR mode?”.”
- “My phone – a Huawei Honor 5X – lacks one, despite being a pretty middle-of-the-road device.”



Mobile AR Support is Lacking in Phones

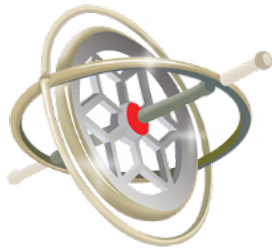
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<http://gaming.stackexchange.com/questions/272904/how-do-i-get-pokemon-go-to-detect-my-phones-orientation>

“Problem #9: "Cannot detect your phone's orientation" error when switching to AR mode.

This is a problem a few of our readers recently reported. Searching the web it appears the issue could be one of two things:

Android - your phone may not have a gyroscope. **If so, AR mode will not work.** A few phones reporting this issue are Sony Experia, HTC 626S and all Huawei smartphones.”



- Must use Gyro and NOT Compass
 - Compass Response time not fast enough
 - Can't use Compass Indoors because of environmental magnetic distortions caused by metal and electromagnetic waves
 - **User Experience**: Gyro allows Real time response without delays
- Sensor Fusion depends on Gyro Noise, Gyro Offset, and Gyro Sensitivity
 - Same specs that make INVN a leader in OIS applications
 - INVN offers Best Gyro Noise/Offset/Sensitivity in Industry. Key spec:
 - **User Experience**: Orientation stays fixed to the real world so that Pokeman stays in same location even after user hand movement
- Mobile gets hot because GPS, AP/Graphics, Display and Gyro on 100%
 - INVN offers best Gyro Offset vs. Temp spec: 0.01 dps/°C
 - See Video showing **major drift** on Non-Invensense Gyro based phones
 - **User Experience**: Pokeman won't drift over camera scene as mobile temp increases

Gyro Offset vs. Temp Setup

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	Test Case	Benchmark Phones	Test Condition (Recoding time @ Temp)	Test Result (Error in degree) (Competition vs INVN)
A/M/G 9X Rotation Vector	1	iPhone5S vs. iPhone6+	7 min @ heat up ↗43° C	90° VS 1°
	2	Xiaomi5 vs. iPhone6+	3 min @ heat up ↗43° C	30° VS 1°

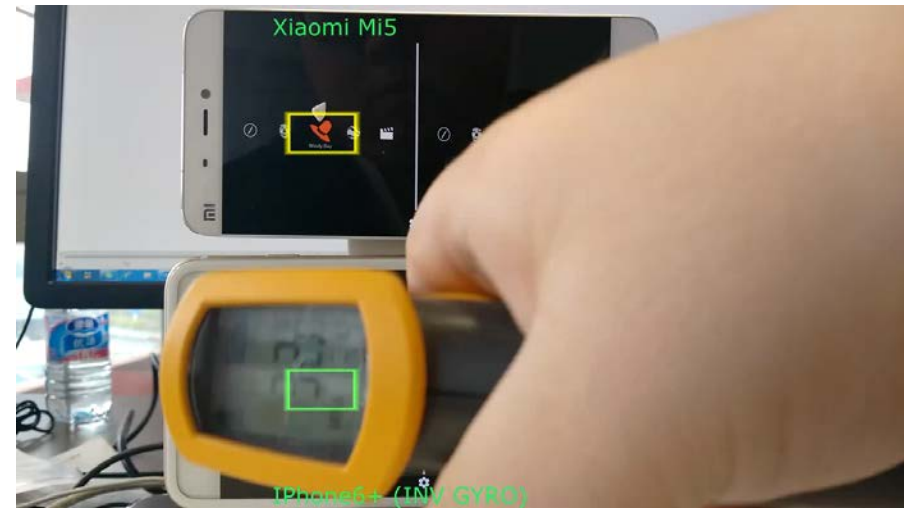
* Create a $\pm 1^\circ$ Degree @1Hz Swing test environment to simulate the real Handset and HMD user case of AR/VR

Gyro Offset vs. Temp Video

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iPhone 5S vs iPhone 6+ | 7 min @ heat upto 43°C



Xiaomi5 vs iPhone 6+ | 3 min @ heat upto 43°C

ICM20602/03 Competitive Analysis

Spec	ICM-20602/03	BMI055	BMI160	LSM6DS3
Package	3x3x0.75mm LGA	3x4.5x0.95mm LGA	2.5x3x0.83mm LGA	2.5x3x0.83mm LGA
Gyroscope FSR	±250/500/1000/2000 dps	±125/250/500/1000/2000 dps	±125/250/500/1000/2000 dps	±125/245/500/1000/2000 dps
Gyroscope ZRO at 25°C	±1dps TYP	±1dps TYP	±3dps TYP	±10dps TYP
Gyroscope ZRO over Temperature	±0.01 dps/°C TYP (-40°C to +85°C)	±0.015 dps/°C TYP (-40°C to +85°C)	±0.05 dps/°C TYP (-40°C to +85°C)	±0.05 dps/°C TYP (-40°C to +85°C)
Gyroscope Sensitivity Tolerance	±1% TYP	±1% TYP	N/A	N/A
Gyroscope Sensitivity over Temperature	±0.016%/C TYP (-40°C to +85°C)	±0.03%/C TYP (-40°C to +85°C)	±0.02%/C MAX (-40°C to +85°C)	±0.012%/C TYP (-40°C to +85°C)
Gyroscope Noise	0.004 dps/√Hz TYP	0.014 dps/√Hz TYP	0.007 dps/√Hz TYP	0.007 dps/√Hz TYP

ICM20603 Competitive Analysis

Spec	ICM-20602/03	BMI055	BMI160	LSM6DS3
Accelerometer Offset at 25°C	Comp: ±25mg TYP Board: ±40mg TYP	±70mg TYP	Comp: ±25mg TYP Board: ±40mg TYP	±40mg TYP
Accelerometer Offset over Temperature	X & Y-axis: ±0.5 mg/°C TYP Z-axis: ±1 mg/°C TYP (-40°C to +85°C)	All axis: ±1 mg/C TYP	All axis: ±1 mg/C TYP	±0.5 mg/°C TYP
Accelerometer Sensitivity Tolerance	Comp: ±1% MIN/MAX	N/A	N/A	N/A
Accelerometer Sensitivity over Temperature	±0.012%/C (-40°C to +85°C)	±0.02%/C TYP (-40°C to +85°C)	±0.03%/C TYP (-40°C to +85°C)	±0.008%/C TYP (-40°C to +85°C)
Accelerometer Noise	100µg/√Hz TYP	150µg/√Hz TYP	180µg/√Hz TYP 300µg/√Hz MAX	90µg/√Hz TYP

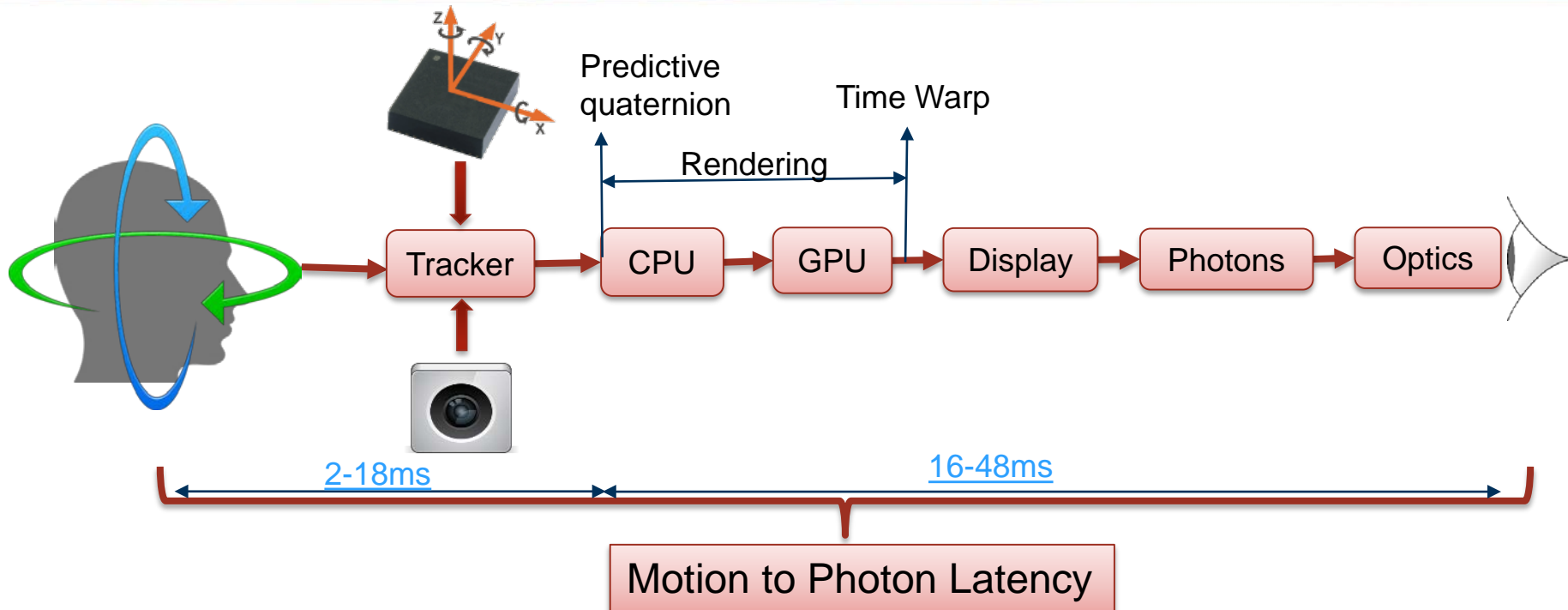


Sensor Platform System Solutions



Motion to photon latency (accuracy)

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- **Motion to photon Latency:** [2] Difference in person's expectation to what is displayed
 - **Issue:** Disorientation and nausea attributing to motion sickness
 - **Solutions:**
 - **Lower latency in Motion detection & Sensor fusion**
 - Accurate motion estimation (6 DOF = **3DOF** → **Orientation** + 3DOF → Translation)
 - **Predictive quaternion**
 - Time warping use case
 - Higher frame rate (Faster rendering)
 - OLED display for faster refresh rate

6-axis Gyro/Accel Use Cases

All-in-One HMD



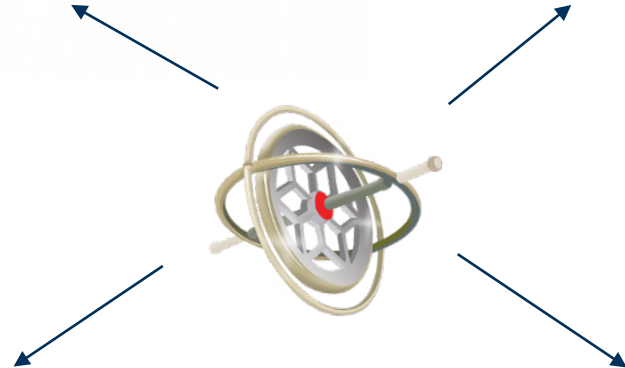
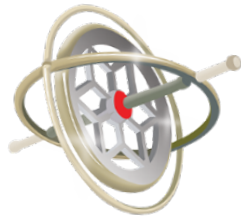
Mobile AR/VR Platforms



VR Headset



VR & HMD Controller



- Head Tracking
- Remote Control Orientation and Translation

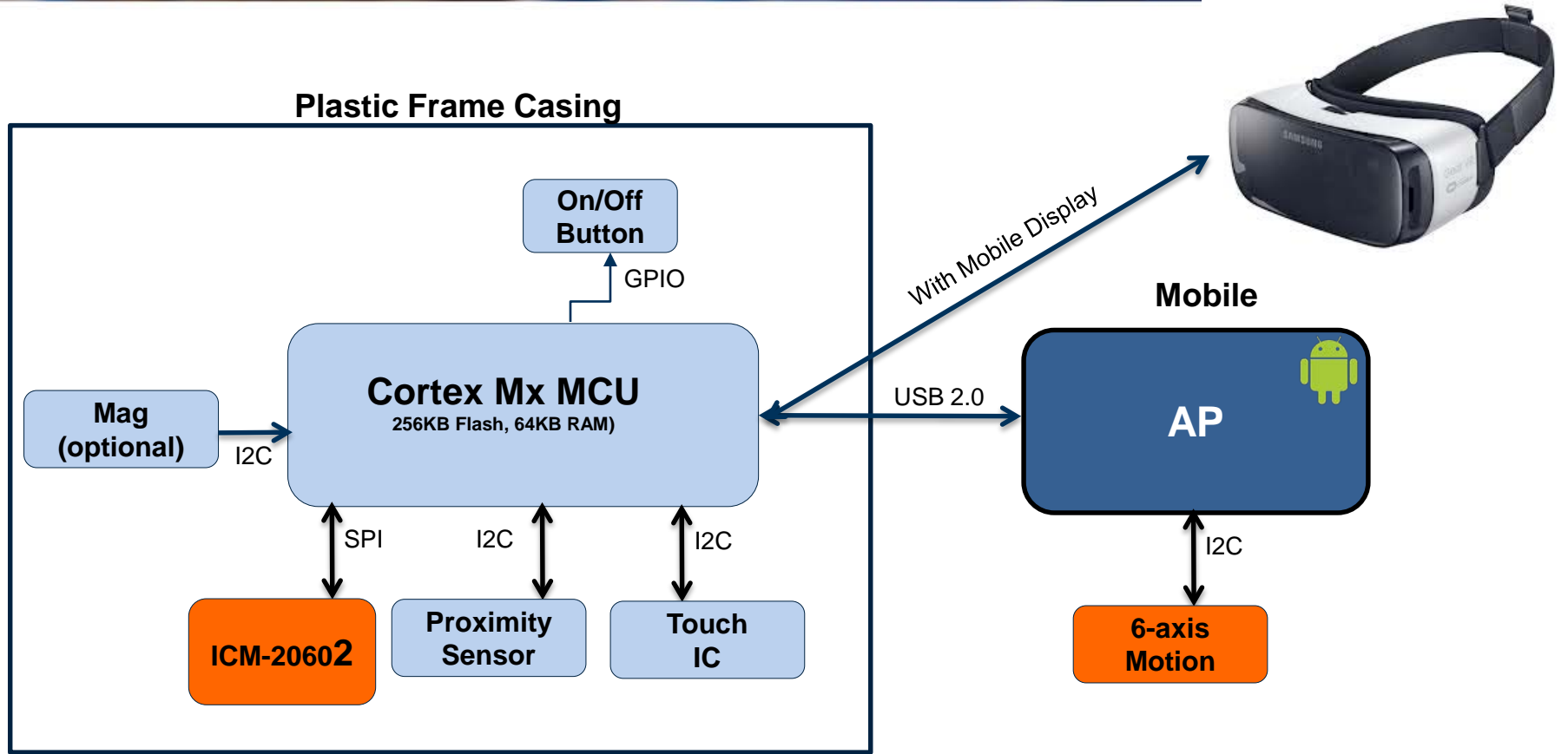
- Headtracking:
-]“Cardboard” type headset – Sensors only on Phone

- Head Tracking

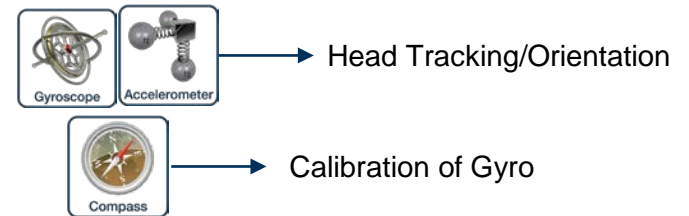
- Remote Control Orientation and Translation

VR Headset Architecture (GearVR)

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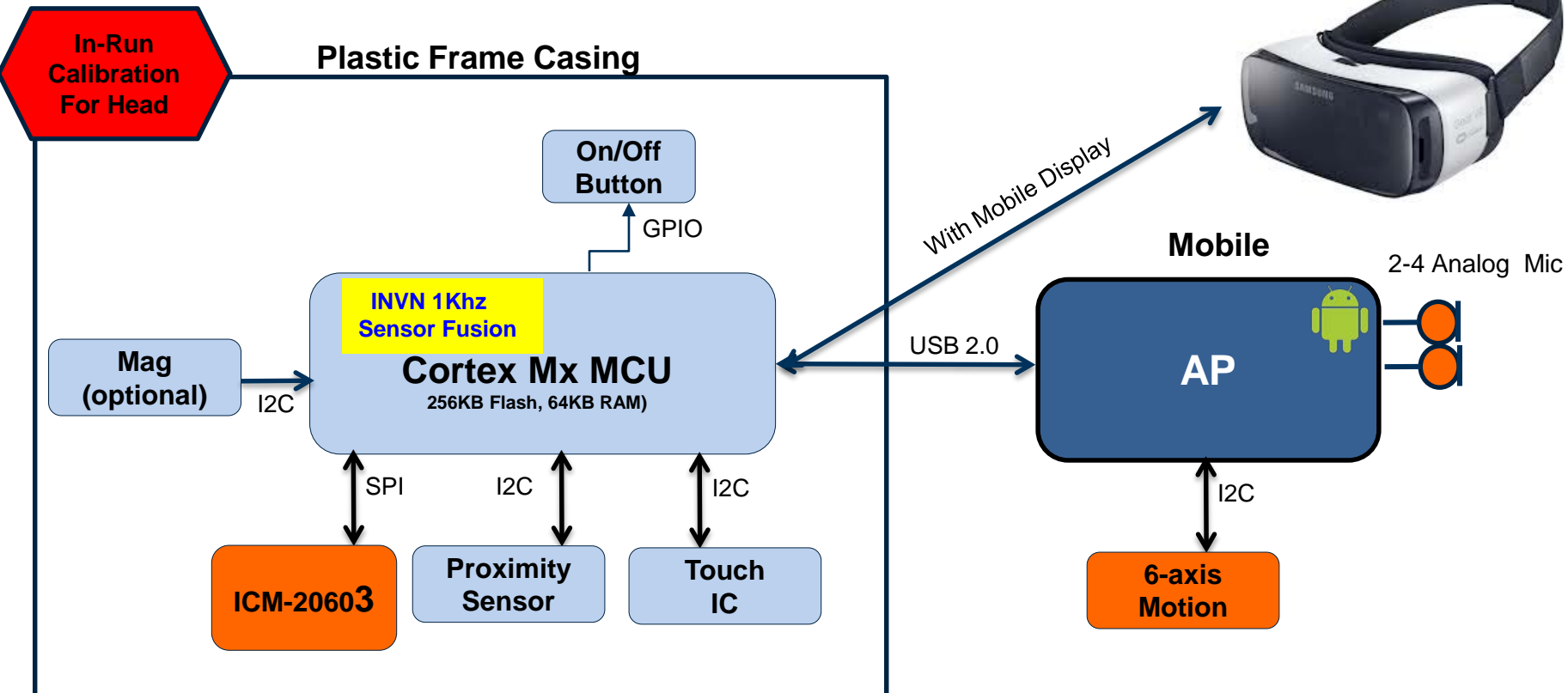


Offering #1 – Sensor Only

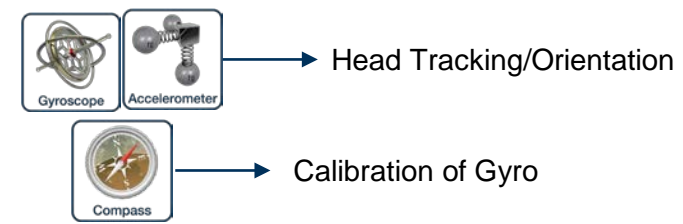


VR Headset Architecture (ie. GearVR)

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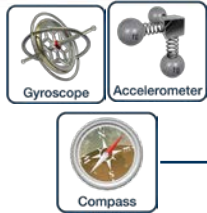


Offering #2 – Sensor + SW (Embedded)



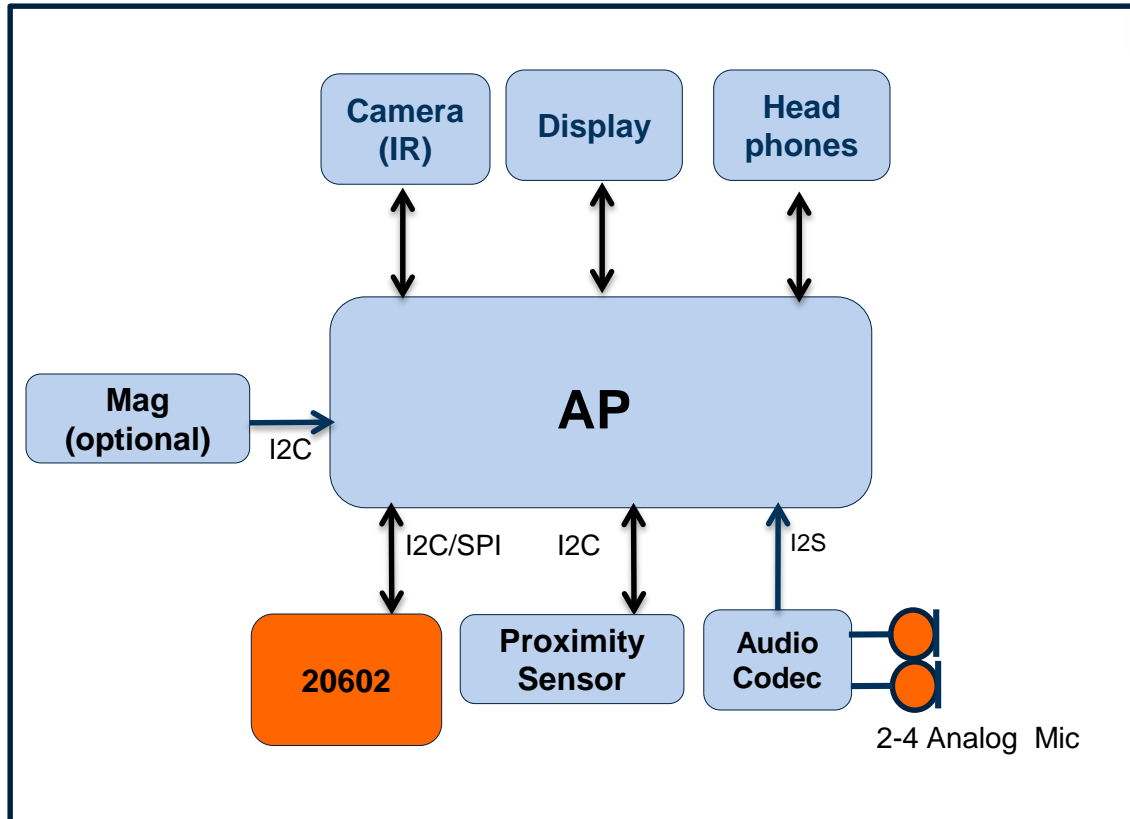
“All-in-One” Type Architecture

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Head Tracking/Orientation

Calibration of Gyro



Offering #1 – Sensor Only

“All-in-One” Type Architecture

sensing the
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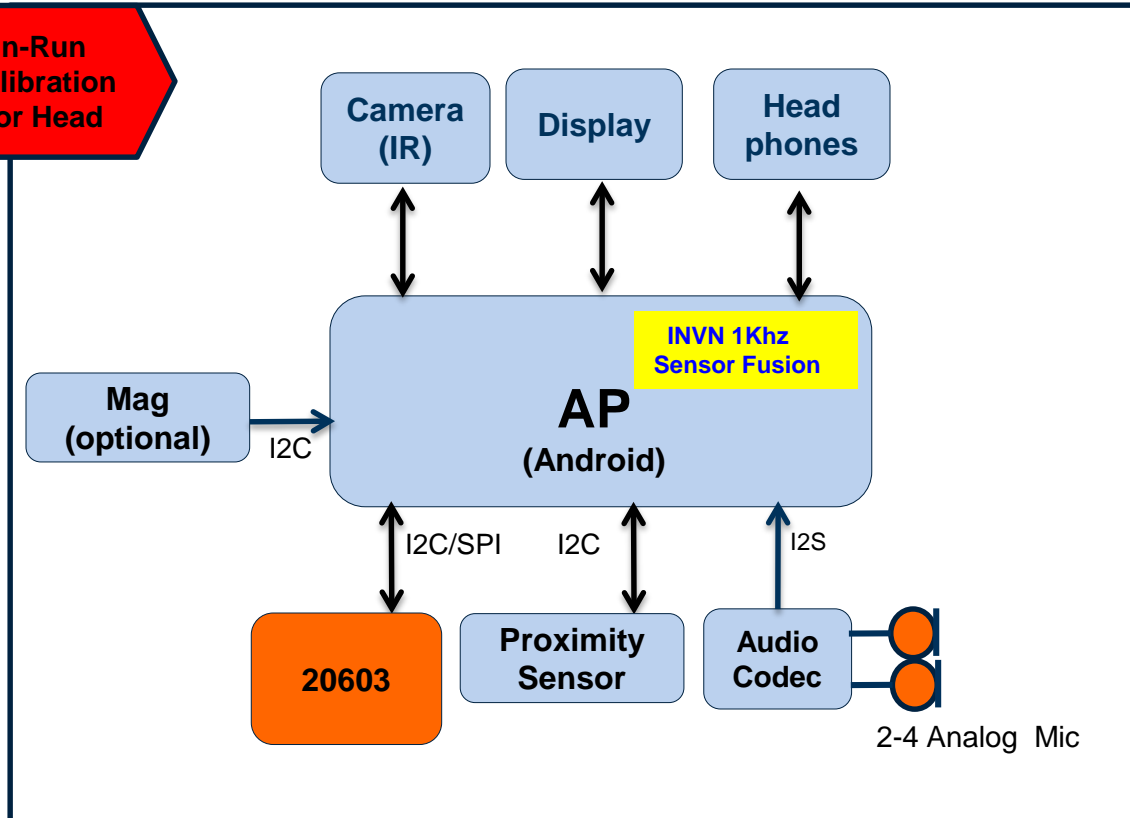
Head Tracking/Orientation



Calibration of Gyro



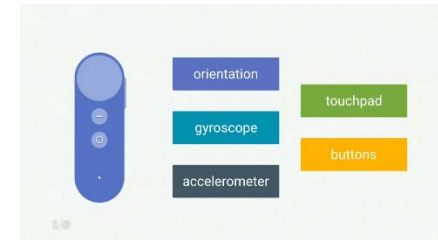
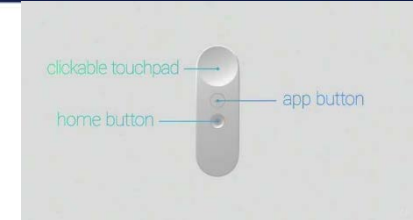
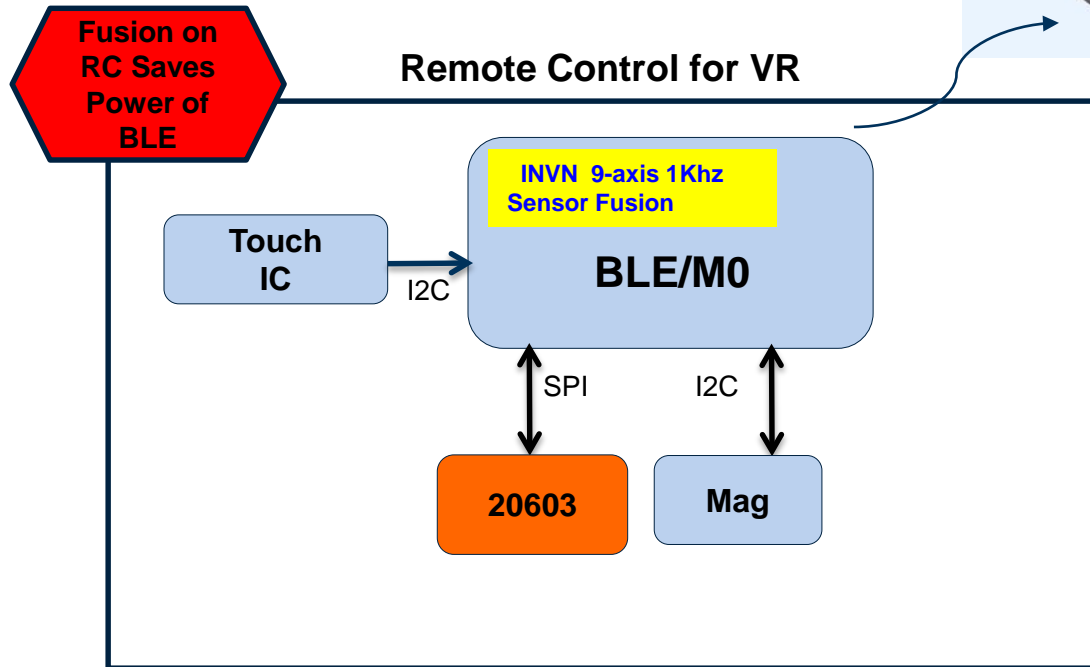
**In-Run
Calibration
For Head**



Offering #2 – Sensor + SW (AP Direct Connect)

Fusion Library for Remote Control

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Offering #1 – Sensor + SW



→ Head Tracking/Orientation



→ Environment Tracking

Sensor Specs

- Gyroscope FSR: ± 2000 dps
- Accelerometer FSR: ± 16 g
- No DMP
- VDD: 1.71V or 3.45V
- FIFO: 1Kbytes
- SPI: 10MHz SPI
- I2C: 400kHz (Host Interface)
- AUX I2C: Not Supported
- INT pins: 1
- Package: 3x3x0.75mm MAX 16-pins LGA

1KHz Sensor Fusion Library

	20603 Requirements
Performance Targets*	Relative Heading Error Static - <1 Degree Relative Heading Error Dynamic - <3 Degree Pitch/Roll Error (6-axis) Static – <1 Degree Pitch/Roll Error (6-axis) Dynamic – <2.3 Degree

* Uniform Magnetic Field; Ambient Temp; Factory Cal assumed to be done

Date	Releases	System Requirements	Features Supported
Oct 28 th	Lite Release 1.6.1	Algo: 15KB Driver 20603: 6.5KB AKM Driver: 5KB *1.6.0 Release with AKM09911 Driver integrated	Raw/Cal Accel Raw/Cal Gyro Raw/Cal Mag GRV RV



Thank You

