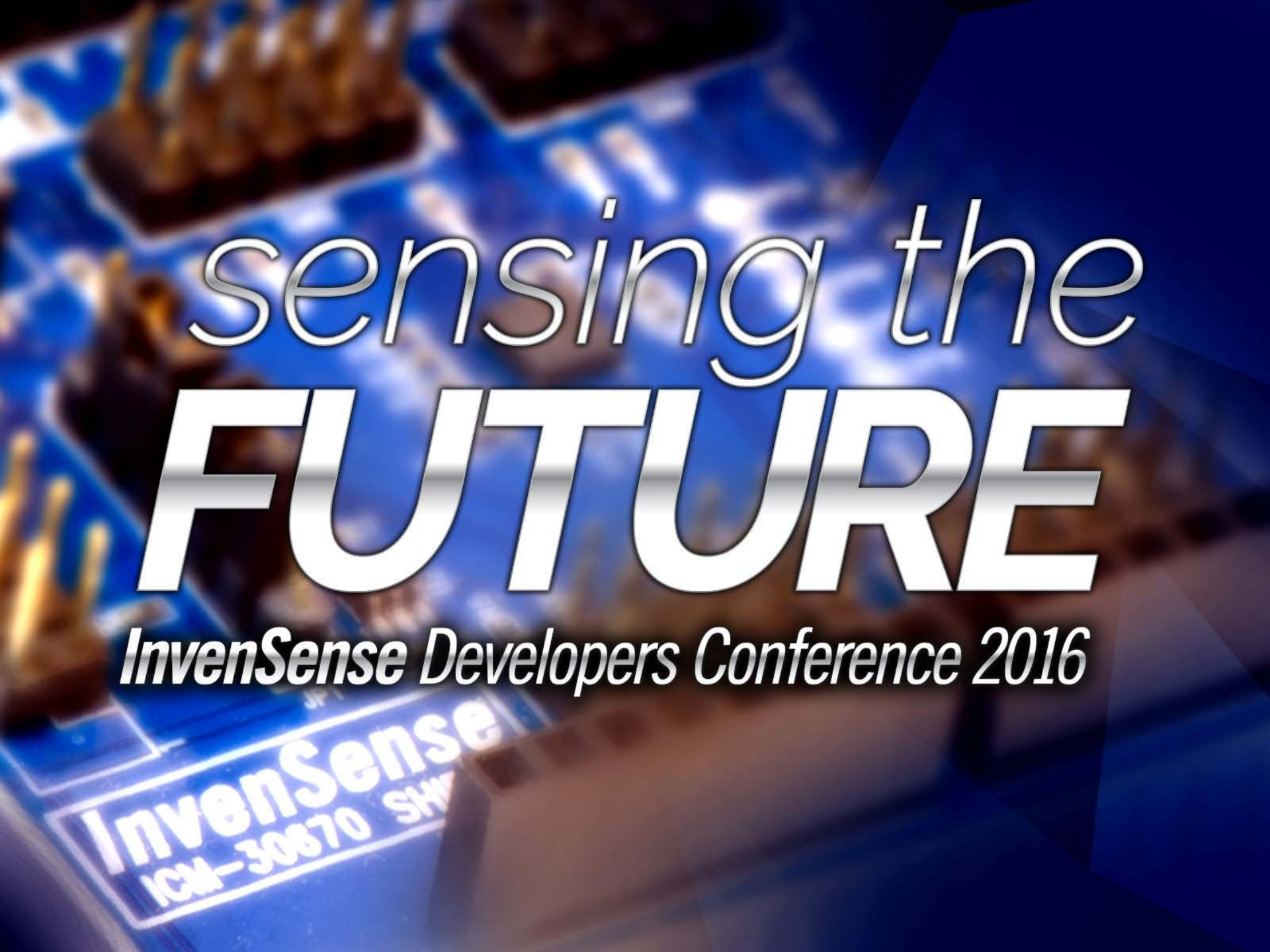

sensing the
FUTURE
InvenSense Developers Conference 2016
InvenSense
ICM-30670

Wearable Success Stories

sensing the FUTURE

Zepp
ITG-3701

Octonion
MPU-9250

Bragi
MPU-9250
MPU6500

Sony
MPU-6500

FireFly SoC + Audio Mics + 6/9-Axis

Intel/Fossil
ICS-43432

LG Urbane 2 Watch
MPU-6515

Qiwo Smart Watch
ICM-30630

Fitbit Surge
MPU-9250

SK Telecom
MPU-6555

Zikto
MPU-6555

INVN inside HMD/VR/Smart Glasses

sensing the FUTURE

Microsoft HoloLens

Oculus/Facebook

HTV Vive

INVN Delivers the Required Sensor Performance for HMD/VR

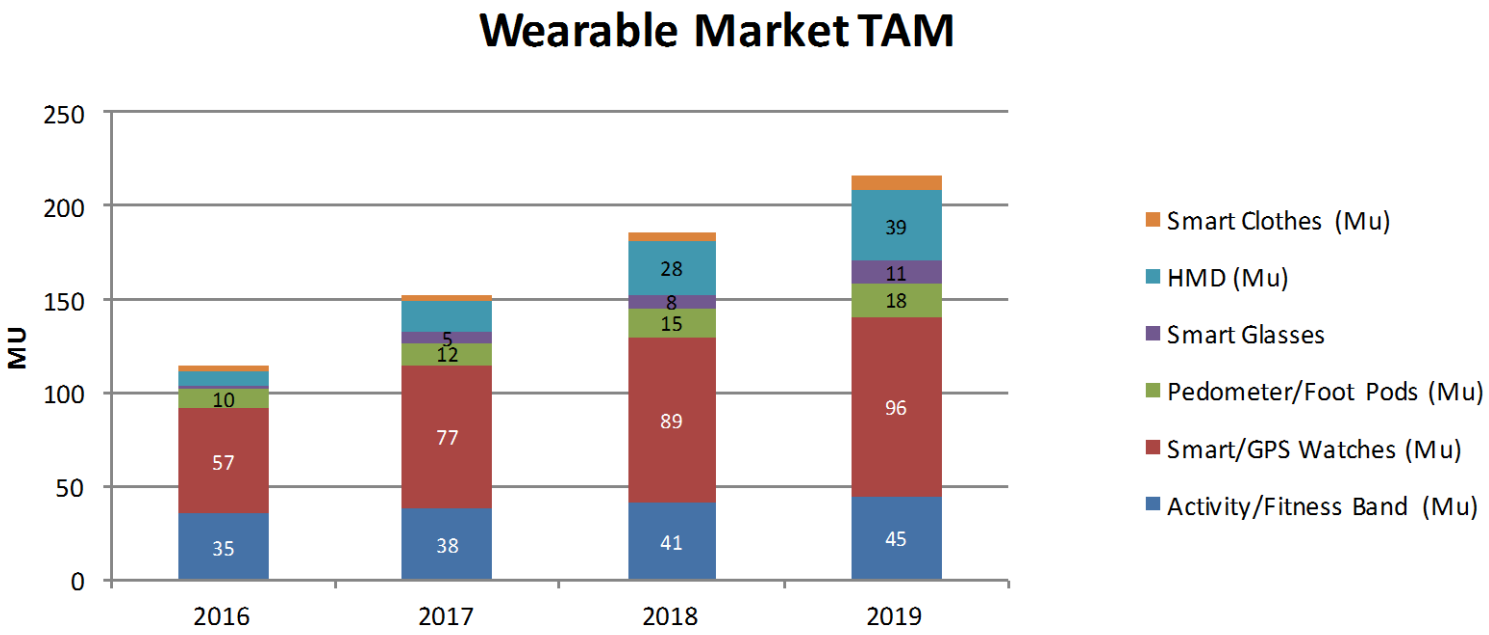
Vizux M100

Epson Moverio

ODG M-7

Wearable Market Size & Trends

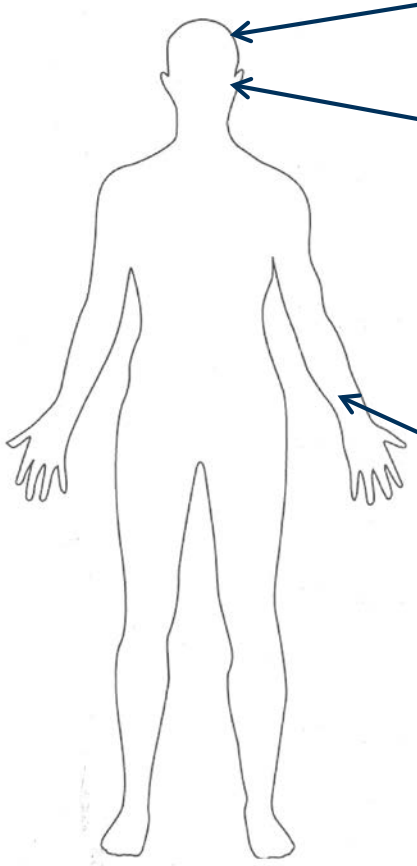
sensing the FUTURE



- **Top 5 OEMs**
  - Apple
  - Xiaomi
  - Fitbit
  - Samsung
  - BBK
- **Key Market Trends**
  - Accuracy is key focus
  - Need services to create stickiness with Device
  - All-in-One Wrist worn devices will dominate
  - HMD/VR Growing fast
  - Earable Market growing Smart

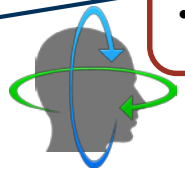
The Anatomy of Wearable Challenges

sensing the FUTURE



Head (HMD/VR/AR)

- High Performance Gyro for Headtracking
- Low latency and Accurate 9-axis Fusion Library with In-Run Calibration for Head Use Case



Ear (Smart Earable)

- Low Power Tracking of Steps, Activity, HRM, Distance, Gestures

Wrist (Smart Watch/Fitness Band)

- Low Power Tracking Analytics, Context, Vital Sign Monitoring
- Industrial Design considerations for water and dust proof
- Motion Correction for PPG
- Extend GPS Watches Battery Life

Step Count isn't Enough

sensing the FUTURE

Wearable Market Today is Pedometer Only:

- Step Count isn't valuable after a while
- Hard to deliver Cloud Services on Step Count only
- Calorie info is not accurate

Wearable Market Moving to Context/Activity:

Android Wear Requirement (Since Android-L release)

Better Data Analytics to Deliver Targeted Services

More Accurate Calorie Count

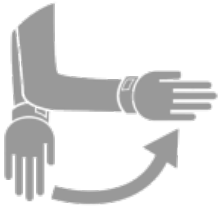
Gestures for UX Control

sensing the FUTURE

Wearable Market Today Reauires Touch:

- Requires Both Hands for UX Control

Wearable Market Moving to ”Touch Less”:



B2S Gesture

Shake Gesture (For Wrist)

- Flick Wrist Out
- Flick Wrist In
- Push Arm Down
- Push Arm Up
- Shake Wrist to Exit

“TouchLess” Menu Control

Vital Sign Monitoring

sensing the FUTURE

Wearable Market Today has HRM (but with varying Accuracy):

- HRM Works well while in No-Motion
- In-Activity HRM is not accurate
- Lack of Accuracy hurts the Services

Wearable Market Requires Accurate HRM:

Android Wear 2.0 Requirement

Better Health Data to Deliver Targeted Services

More VITALS Coming

GPS For Tracking

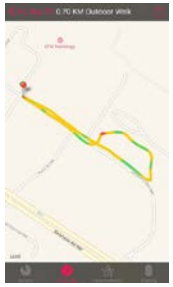
sensing the FUTURE

Wearable Market Today is ADOPTING GPS:

- GPS used for Speed/Distance/Route Tracking
- GPS impacts Battery Life Dramatically
- GPS has Inherent issues for usability(Trees, urban canyon)

Wearable Market Needs GPS to be USABLE:

Track User while GPS is Off



Keep Track of Actual Path Run/Walk

Apple Watch 2 Demonstrates Usable GPS

Sensor Platform System Solutions

Wrist Worn Health/Fitness Feature Set

sensing the FUTURE

Green – Available Now
Red - On Roadmap

Activity/Context
Steps, Activity, Sleep

Vital Signs Monitoring
PPG Motion Artifact Correction
HRV
Blood Pressure

OEM Health/Fitness Cloud

Health Services

GPS

Sensor Assisted GNSS
Running: Speed/Distance/Route
Biking: Speed/Distance/Route

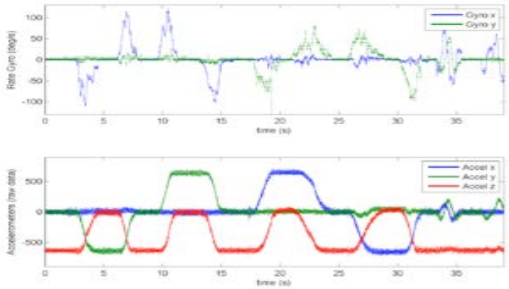
Barometer Support
Floors Climbed

Activity/Context Solutions

sensing the FUTURE

6-axis Raw Data Sensor ICM-20602

Raw Data Sensor

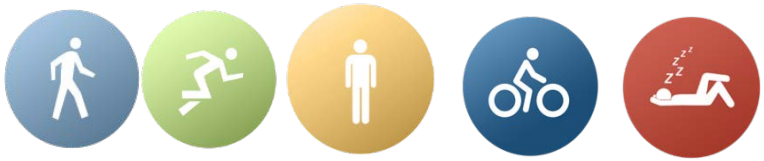


6-axis "Smart" Sensor ICM-20648

Activity- Classifier B2S

Wearable FireFly™- ICM-30631/2

Activity



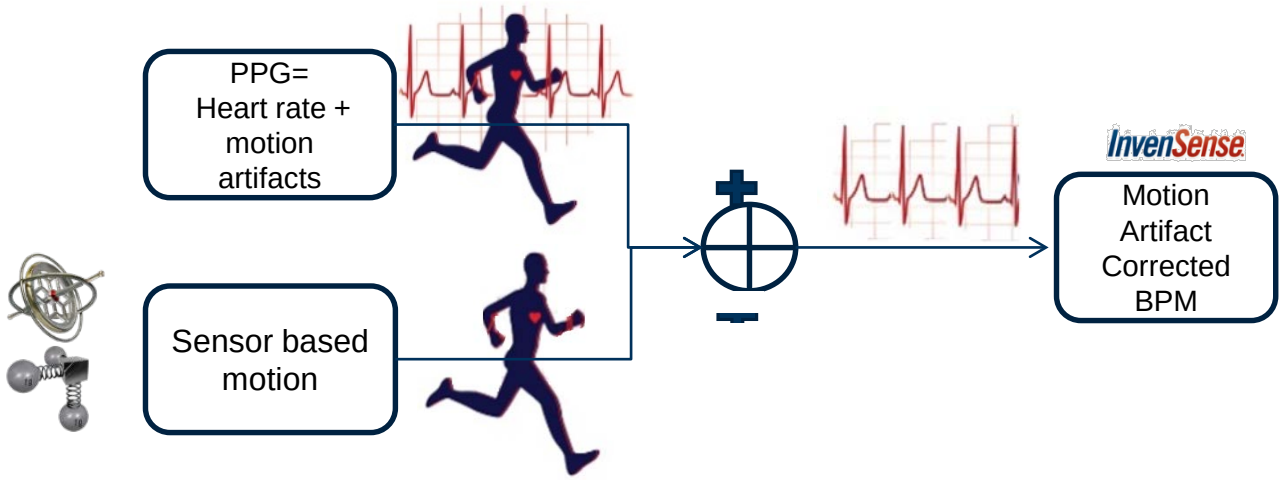
Statistics

Sensor Support

Gestures

INVN Motion Artifact Correction

sensing the FUTURE



PPG Sensors Supported

PAH8001
PAH8002

PPS960
(AFE4404)

ADPD174

Test Definitions	Mean Absolute Error (MAE) [bpm]		Standard Deviation (σ) of Residuals [bpm]		Percent of Values within ±10bpm [%]	
	Android Specs	InvenSense	Android Specs	InvenSense	Android Specs	InvenSense
Sedentary Heart Rate	< 5.00	2	< 8.00	4.5	> 90	97.2
Indoor Walking	< 5.00	3.4	< 8.00	6.1	> 85	92.9
Running	< 7.50	4.1	< 8.00	7.4	> 80	90.8
Elliptical	N/A	2.6	N/A	5.2	N/A	95.1
Combined	N/A	3.8	N/A	5.2	N/A	91.9

INVN Performance: High Pulse →Low Pulse Transitions

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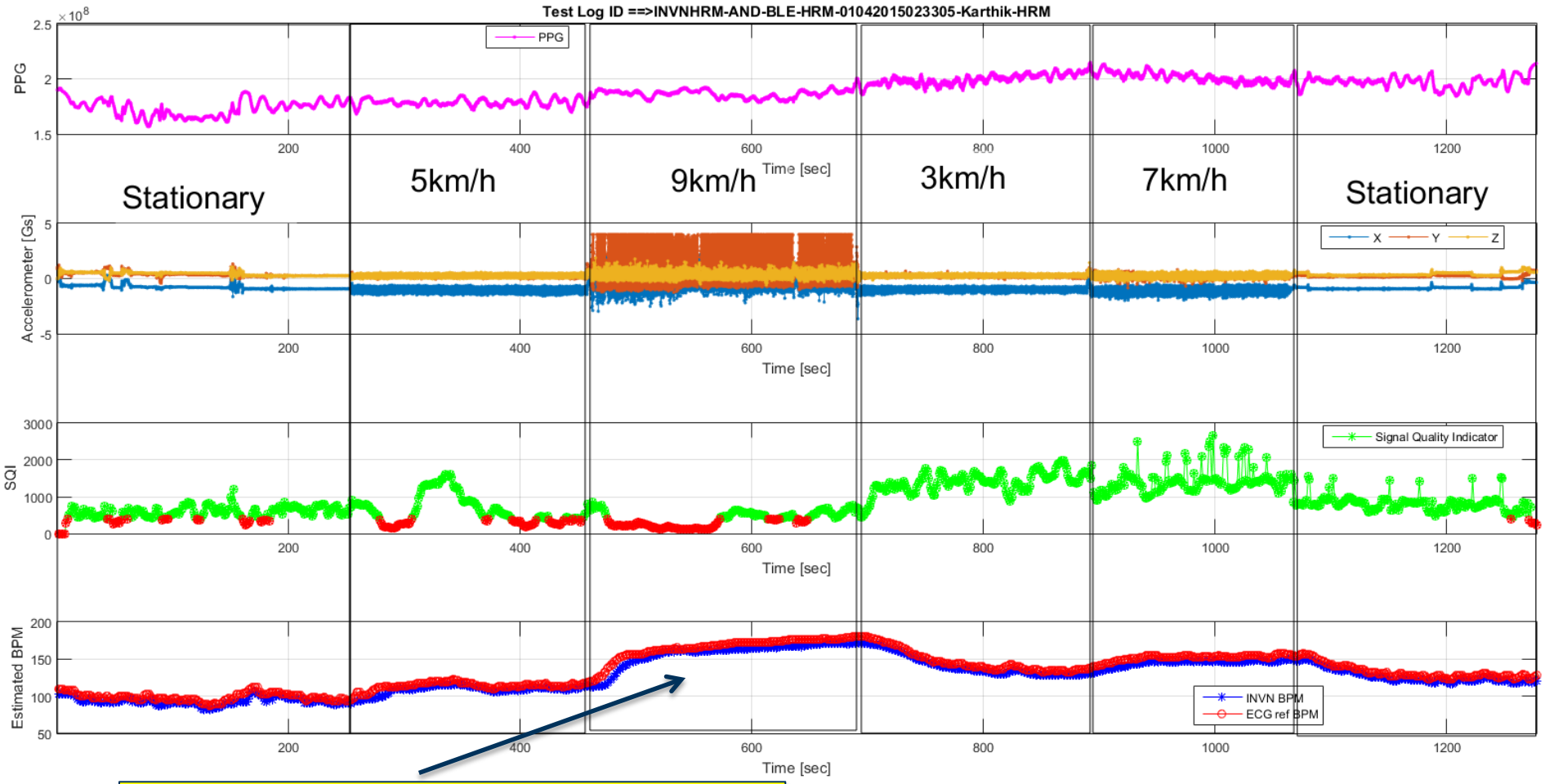


INVN HRM algorithm able to RELIABLY conduct motion artifact removal resulting in good BPM tracking

FireFly™: ICM-30630

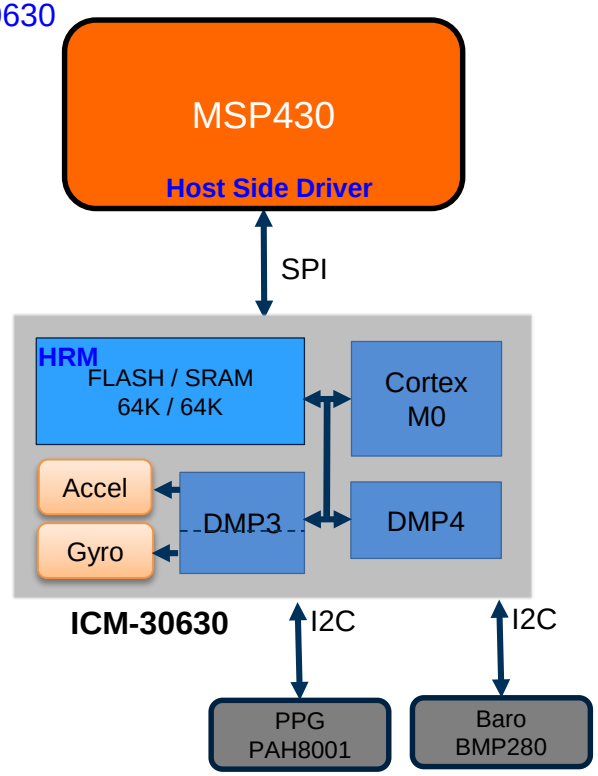
sensing the FUTURE

- **Hierarchical Tri-Core Processing**
  - ARM M0: Open Platform
  - DMP4: Android L offload (Fusion, BAC, Pedo)
  - DMP3: FFT
- **Low Power Processing (M0+DMP < M4)**

Test Condition	Current (uA)
Standby (No functionality)	52
Bring-To-See Gesture	354
Pedometer only[1]	210
Activity Classifier	176
HRM (PPG Sensor not included)	900

"**Master**" – Required to boot up 30630

"**Slave**" – Processes Wearable Sensor Features at Low Power



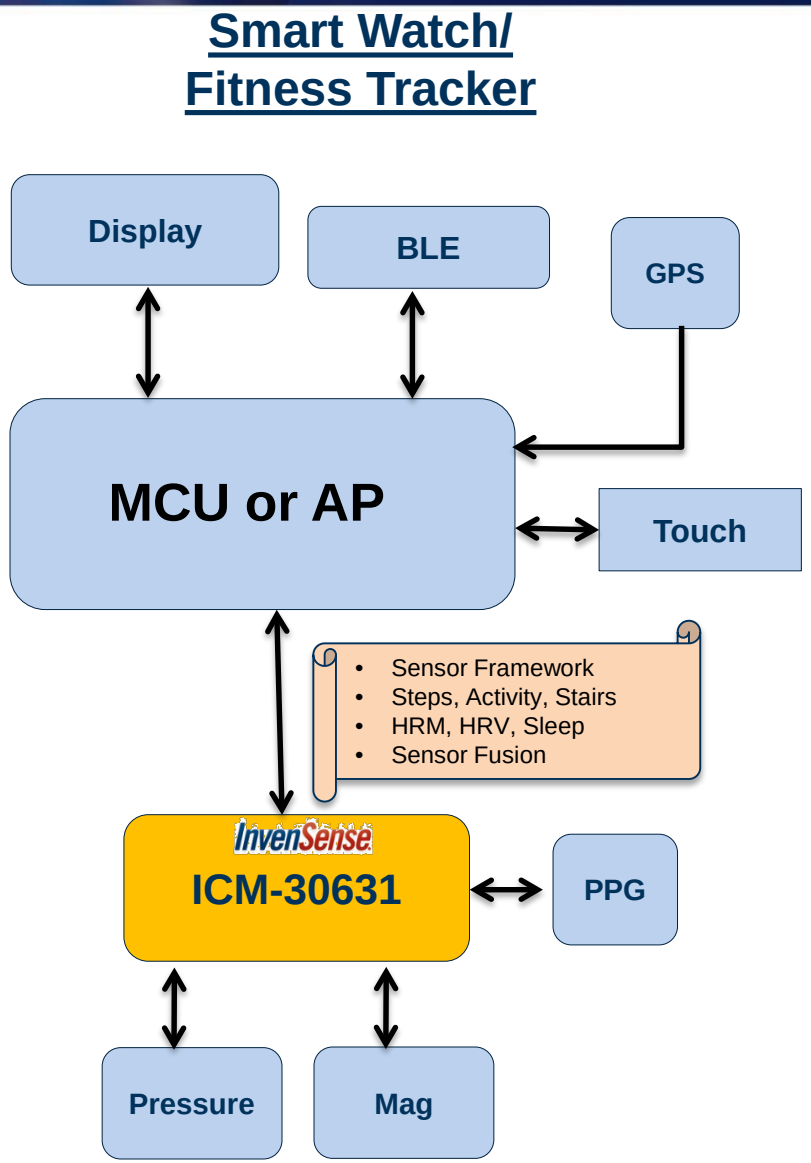
- **Available/Free resources – Open Sandbox**
  - Memory: ~32KB SRAM (incl FIFO) + ~32KB Flash

- **Complete Wearable SW Features**
  - See Next Slide

ICM-30631/32 value Prop

sensing the FUTURE

- **Complete SW Stack "out of box"**
  - Customer uses baseline features form INVN
  - Customer focus their SW resources on Differentiated Features of their product
- **Power**
  - ICM-30631
    - BAC – 172uA
    - HRM Motion – 900uA
  - STM32 MCU + CYWEE SW Stack
    - Activity Algo – 850uA
    - HRM Motion – 2mA
- **Integration**
  - Sensor, MCU and SW from one Vendor



30631/32 Default Feature Set

sensing the FUTURE

Category	SW Feature	ICM-30631	ICM-30632
Hardware Sensor	Accelerometer	Yes	Yes
	Gyro	Yes	Yes
	Pressure (BMP280)	Yes	**No**
	Mag (AKM09911)	**No**	Yes
	Proximity (CM36671)	**No**	Yes
	PPG (PAH8001/2, ADPD174, PPS960)	Yes	**No**
Fitness/ Wellness Feature	Walk,Run, Bike,Still, (Pedometer)	Yes	Yes
	Walk/Run Step Counter	Yes	Yes
	Walk/Run Time Accrual	Yes	Yes
	Stand/Sit Time Accrual	Yes	Yes
	Sedentary Reminder	Yes	Yes
	HRM Motion Correction	Yes	**No**
	Heart Rate Variation (HRV)		
	Sleep Analysis (Manual Entry)	Yes	Yes
	Calorie Counter (Activity)	Yes	Yes
	Distance (walk/run)	Yes	Yes
	Floor Climbed Counter (& BMP280 Temp)	Yes	**No**
Gestures	Shake	Yes	Yes
	DoubleTap (with B2S first)	Yes	Yes
	B2S	Yes	Yes
Android Sensors	Android Fusion: Gravity, Linear Accel, Orientation (RV, GRV, GEOMAG)	GRV only	Yes

No = Not Supported
Yes = Part of Default 3063x Image

30632-4.1.0 Feature accuracy

sensing the FUTURE

Features	Metric	4.1.0 Typ Performances	
Pedometer (Normal Continuous Walk/Run)	Absolute Error	Walk: Run:	**5 %** **6 %**
Distance (Requires User height Input)	Absolute Error	Walk: Run:	**< 10 %** **< 15%**
BAC	Detection rate	Still: Walk: Run: Bike:	**79 %** **93 %** **83 %** **92 %**
Sit/Stand (+BAC)	Detection rate	Sit: Stand:	**82 %** **89 %**
Bring To See	Detection rate	sedentary position: walking/running:	**85 %** **75 %**
Shake *two half-rotations of the wrist in Look at screen position*	Detection rate	sedentary position:	**90 %**
Double Tap *in Look at Screen position*	Detection rate	sedentary position: walking/running:	**85 %** **80 %**

GPS is a Wearable Battery Killer

sensing the FUTURE

Problem: GPS Usage Kills Battery Life

Fitbit Surge:
- 7 day Battery life
- 5hr GPS Battery life

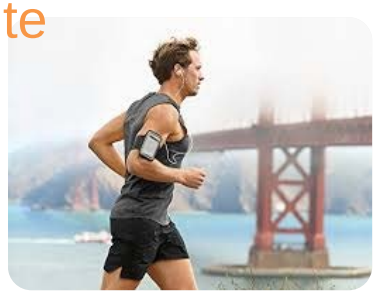
TomTom GPS Watch:
- 17 day Battery life
- 10hr GPS Battery life

Strava Fitness Apps
- 4-6hr Battery Life w/ GPS

Solution: Coursa Sports

Use Less GPS and Keep Accuracy of Speed/Dist/Route

- Sensors + GNSS Integration
  - **Low Power Mode: 50% Lower Power than GPS**
  - OpenSKy: Similar speed/distance Accuracy
  - MultiPath: Improved speed/Dist Accuracy
  - 100% Coverage in Denied Environments
  - Improved Workout Credit
- Available Wrist Worn Wearable and Mobile



Coursa Sports vs. Strava

sensing the FUTURE

Coursa Sports vs Strava vs Reference

Reference
Strava
Coursa Sports

GPS used for Coursa Sports

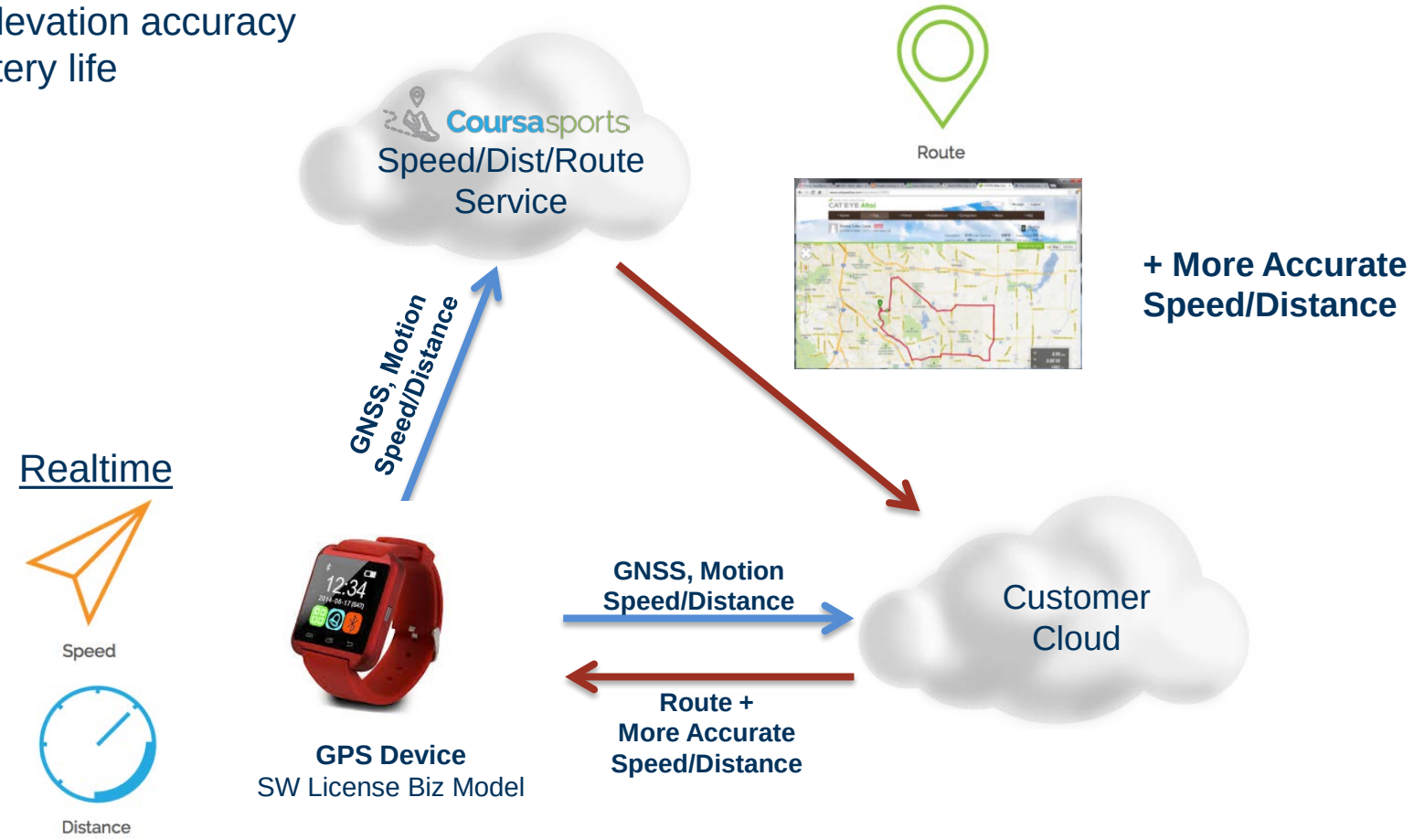
Conclusion
Coursa Sports can deliver the same accuracy as Strava (who uses 100% GPS) but with only 25% GPS

Reference
Coursa Sports

Coursa Sports – for OEMs

sensing the FUTURE

- Eliminate GPS route outages
- More accurate speed/distance
- Improved elevation accuracy
- Extend Battery life



High-Impact Wearable Sports Applications

Accel/Gyro for High-Impact Sports

Sensing Everything

Need:
Gyro 4000dps
Accel 32g

- Point of Impact
- High Angular Velocity

Need:
Gyro 2000dps
Accel 16g

Sports Motion Analysis Application

Sensing Everything

Flash (Data Storage)

BT/BLE

Vibration Sensor

1KHz Sensor Data

MCU (Cortex Mx)

STM 24g

6-axis 16g/2000dps

InvenSense

Flash (Data Storage)

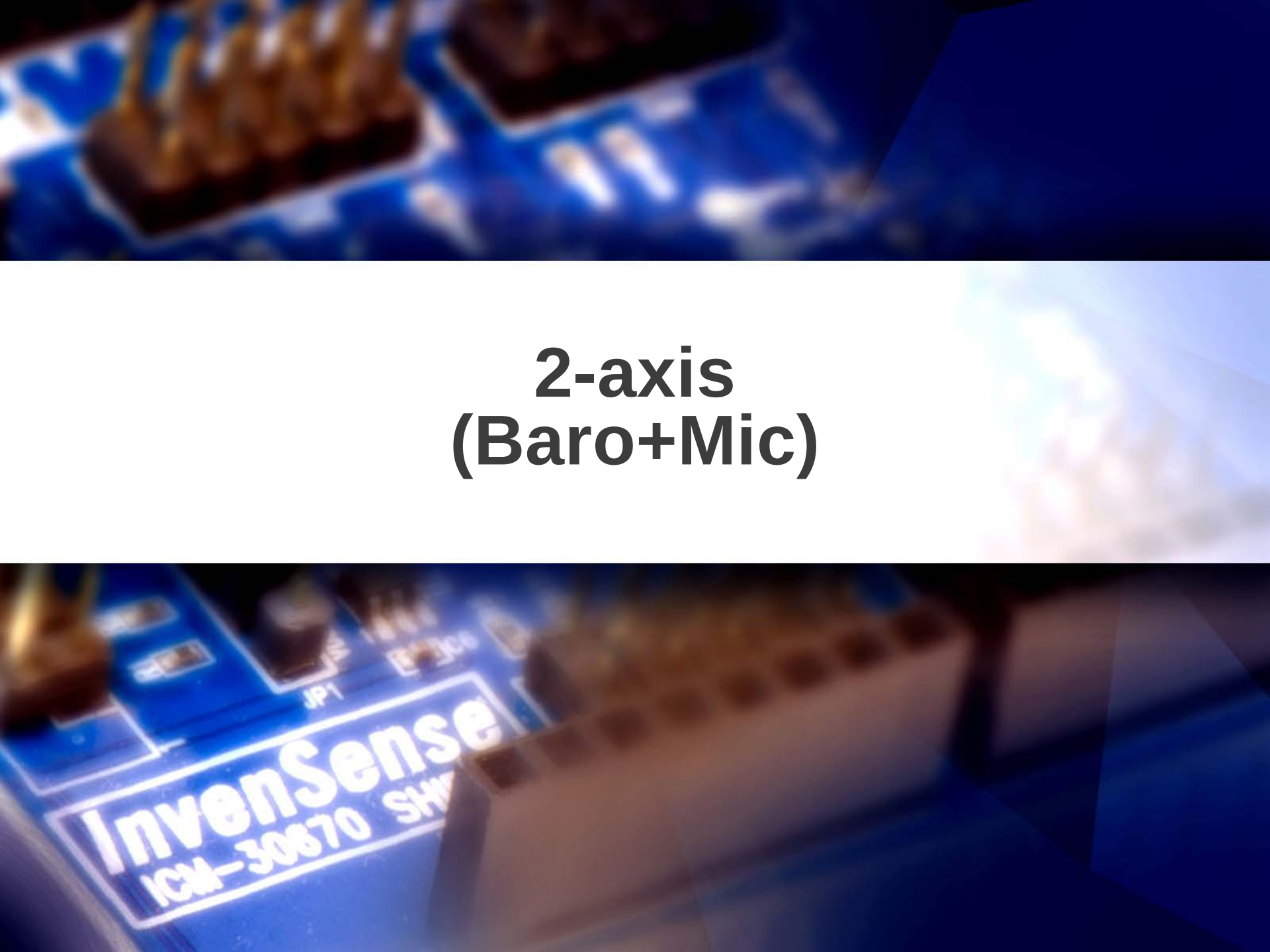
BT/BLE

Vibration Sensor

MCU (Cortex Mx)

ICM-20649 30g/4000dps

InvenSense



2-axis
(Baro+Mic)

#1 Key Value Prop of ICC-51200

Use Case:

1. Mic – “Hi Siri”
2. Baro – Elevation Tracking for Health App

Total Cost of a single “Air Access”

Step	Cost	Note
ID Hole	$0.02	Drilling
Flex PCB	$0.10	Mounted near Hole
Sealing Hole	$0.70-$1.00	System Sealing for Water/Dust with O-Ring and mesh
Total	**$0.82 - $1.12**	

ICC-51200 can address these Products:

sensing the FUTURE

- **<= IP68 (Dust and Water Resistance Level)**
  - ”6” – Solid Particle Protection” No ingress of dust; complete protection against contact (dust tight). A vacuum must be applied. Test duration of up to 8 hours based on air flow.
  - ”8” – Liquid Protection” Ingress of water in harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time (1 m to 3m of submersion). 30mn duration
- **<= ATM5 (Water resistant Level)**

Level	Sweat, Rain Kitchen	Shower Bath	Swimming	Diving
ATM3	**Yes**	No	No	No
ATM5	**Yes**	**Yes**	**Yes**	No
ATM10	**Yes**	**Yes**	**Yes**	**Yes**

Need Waterproof Pressure Sensor

- **Typical Consumer Watch Ratings**

	Apple Watch 2	Samsung Gear3	Motorola Moto360 II	Pebble Time 2	Fitbit Blaze	Garmin Vivo HR
Water/Dust Rating	IPX7 5 ATM (up to 50meters)	IP68	IP67	3 ATM (up to 30meters)	None	5 ATM (up to 50meters)

ICP-101xx Specs Comparison

sensing the FUTURE

Item	InvenSense ICC-51200	Bosch BMP280	Formosa FMB320	GoerTek SPL06-001	ST LPS22HB
Relative Accuracy (hPa)	±10 **Over 300hPa**, 700-1000, 25ºC ±1 Any 10 hPa change	±12 **Over 200hPa**, 700-900 hPa, 25-40°C	±12 **Over 250hPa**, 700-950 hPa, 25-40°C	±6 Pa **Over 100hPa**, 950-1050 hPa, 0-65°C	±10 Pa **Note: Below sea level!** 800-1100, 25 °C
Absolute Accuracy (0-65ºC, Pa)	±1 300-1100	±1 300-1100	±1 300-1100	±1 300-1200	±1(w/o OPC); ±0.1 (w/ OPC)
Noise (Pa)	3 (LP) 0.85 (LN)	3.3 (LP) 1.3 (LN)	1.97 (LP) 0.98 (LN)	5 (LP) 0.6 (sea level)	0.75 (LN)
Temp Coefic. Offset (Pa/°C)	0.2 (25 to 45°C @1000)	1.5 (25 to 40°C @900)	1.5 (25 to 40°C @900)	0.5 (25 to 45°C @1000)	N/A
Current **(@ 1Hz ODR)**	1.1 µA (LP) 5 µA (LN)	2.7 µA (LP) 24.8 µA (LN)	3 µA (LP) 13.9 µA (LN)	3 µA (LP) 40 µA (high pres)	4 µA (LP) 15 µA (LN)
Package (mm)	5.2 x2.7x0.98 8-pin LGA	2x2.5x0.95 8-pin LGA	2x2.5x0.95 8-pin LGA	2x2.5x0.95 8-pin LGA	2x2x0.76 10-pin LGA

ICC-51200 Performance Summary

sensing the FUTURE

- High Performance & Low Power PDM Microphone

Mode	SNR (dBA)	AOP (dB SPL)	Sensitivity (dB FS)	Tolerance (dB FS)	Power (µA)
HPM	64	126	-32	±1	650
SPM	64	120	-26	±1	430
LPM	63	120	-26	±1	185

- Pressure Sensor
  - Best In Class Relative Accuracy
    - ±10 Pa over 700-1000hPa, 25ºC
    - ±1 Pa in 10hPa range 700-1000hPa
      - Corresponds to 0.1m error over 33 floor building
  - Lowest Noise & Lowest Power Consumption
    - 3Pa at 1.1 µA (LP mode) and **0**.85Pa at 5 µA (LN)
  - Best temperature stability at 0.2 Pa/°C

Package Drawing: 5.2x2.7x0.98mm

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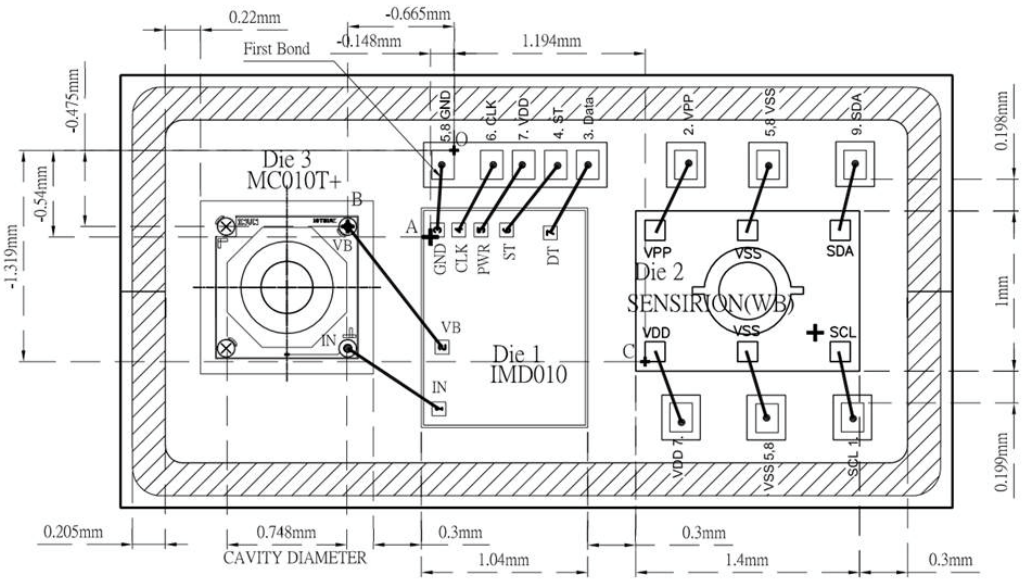

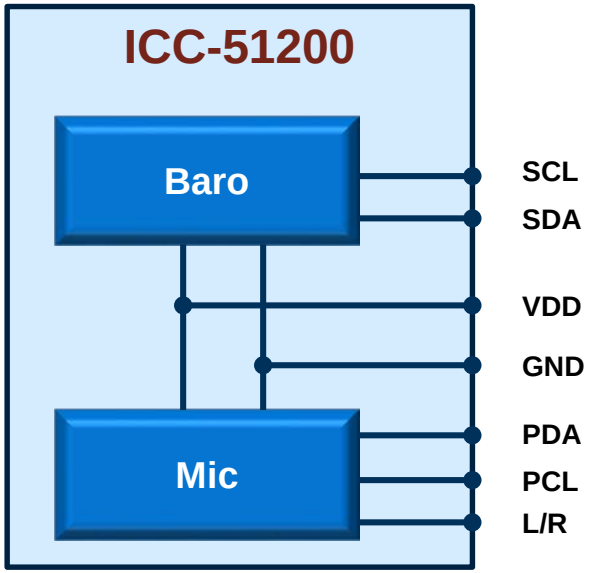

Maintains standard mic package height & width

- No additional space on lower edge of phone
- Same WxH of Standard mic: **5.2x2.7x0.98**mm

Pin Name	Description
SCL	I2C Clock
SDA	Serial Data
VDD	Supply Voltage
GND	Ground
PDA	PDM Data
PCL	PDM Clock
L/R	Channel Select

Note: Additional pins may be needed to improve package stability for baro performance

Thank You