Wearables Tech Applications for Flash Memory

Harsha Nagaraju

July 10, 2015

Agenda

- Micron – Company update
- Wearables Market
  - Various Applications
  - Micron's view of the market
- General Architecture
  - Memory Recommendations
- Future of wearables – Market and Architecture

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Micron at a Glance

Founded: October 1978, Boise, Idaho

FY2014 Net Sales: $16.4 billion

NASDAQ Symbol: MU

Employees: ~30,000 worldwide

Products: We offer one of the world's broadest memory portfolios, including: DRAM components and modules, SSDs, NAND, and NOR, as well as other innovative memory technologies, packaging solutions and semiconductor systems

Markets We Serve: Micron's products are designed to meet the diverse needs of computing, networking, server, consumer, mobile, automotive, and industrial applications

Patents: ~26,000

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Global Manufacturing Scale

1
Boise, Idaho USA
FAB1C DRAM & NAND R&D
FAB1A/X R&D

2
Manassas, Virginia USA
FAB6 DRAM, NAND

3
Lehi, Utah USA (IMFT)
FAB2 NAND

4
Nampa, Idaho USA
FAB9D Imaging

5
Puerto Rico, USA
MPR Module

6
Agrate, Italy
FAB14 NOR & PCM R&D

7
Muar, Malaysia
MMY Package & Test

8
Singapore
FAB7 DRAM
FAB10 NAND
FAB13 NOR
MSB Packaging & Test

9
Taiwan (Inotera)
FAB 11 DRAM

10
Taiwan (Rexchip)
DRAM

11
Xian, China
MXA Test & Module

12
Hiroshima, Japan
DRAM

13
Akita, Japan
Backend

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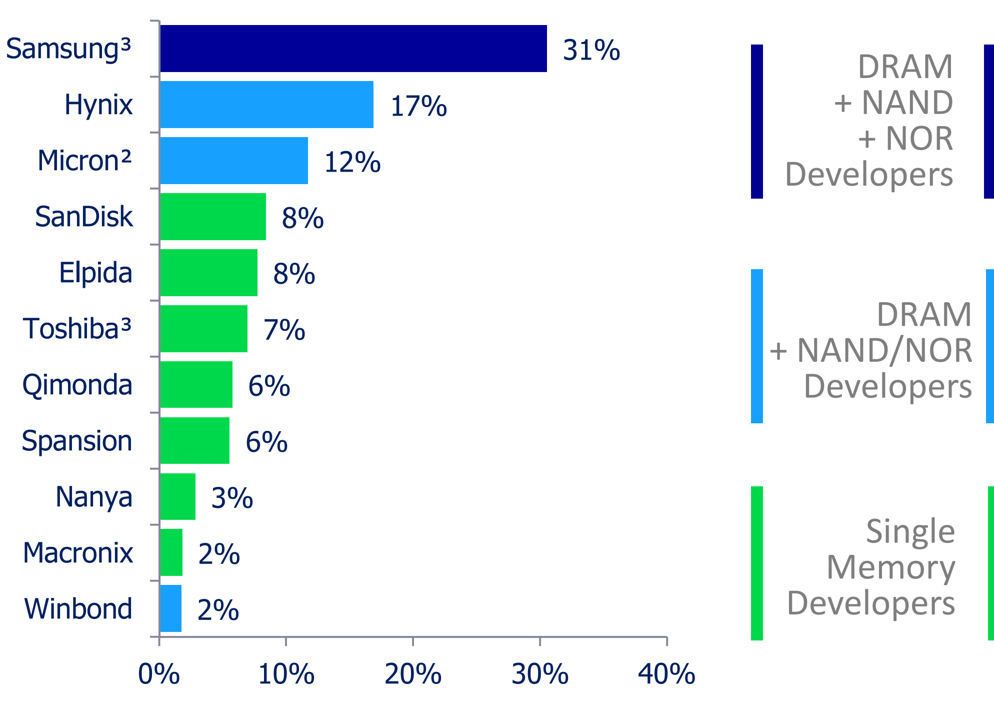
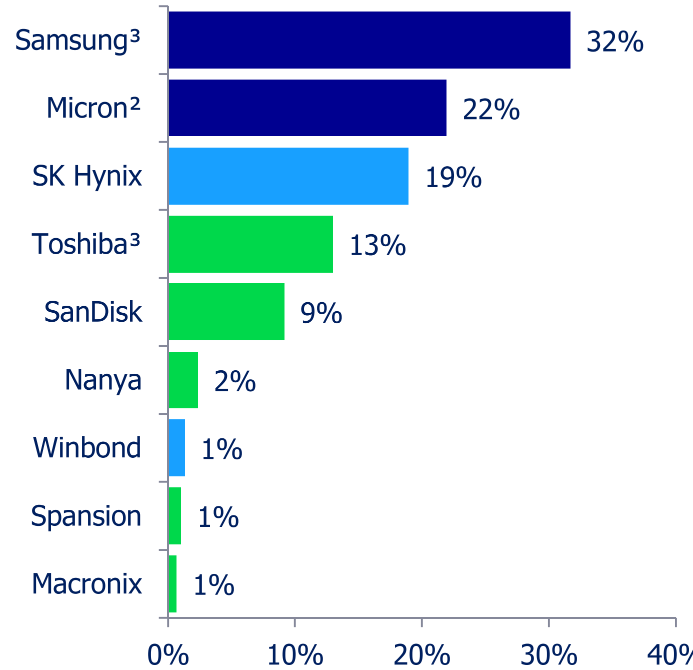
Memory Industry: FY 2008 vs. Today



DRAM + NAND + NOR Developers

DRAM + NAND/NOR Developers

Single Memory Developers



Top Five Market Share: 75%

Top Five Market Share: 95%

Source: Micron
Micron data is from FY 2008; Competitor data is from CQ4-07 – CQ3-08.
1 Group total defined as only those companies listed on this page, although others may also exist. Micron data is fiscal, competitor data is calendar. Percentages vary due to rounding.
2. Micron Includes NAND sold to Intel from IM Flash.
3. Samsung and Toshiba include total memory revenue as reported.

Source: Micron
Micron data is FQ2-13 – FQ1-14; Competitor data from CQ1-13 – CQ4-13 except for Toshiba, Macronix, and Spansion (CQ4-13 not yet available).
1. Group total defined as only those companies listed on this page, although others may also exist.
2. Micron Includes NAND sold to Intel from IM Flash; Elpida revenue prior to merger also included (Dec. 2012 - Jul. 2013).
3. Samsung and Toshiba include total memory revenue as reported.

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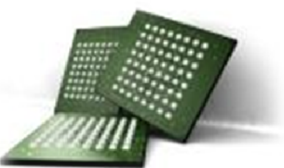
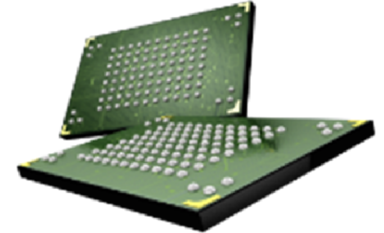
Comprehensive Memory Portfolio for Consumer Solutions

Leading manufacturer of DRAM/NAND/NOR

Complete Memory Portfolio

Serial NOR	e.MMC
SLC NAND	DDR2/3/4
MLC NAND	LPDDR (2,3,4)





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Wearables Market

Wearables – Applications Across Many Markets

Military and Public Safety

Healthcare

Industrial

Identity - Security

Payment

Health & Fitness

Smart Watches

Gaming

IDC Forecasts the Wearables Market will Grow to be a $48 Billion dollar market by 2019

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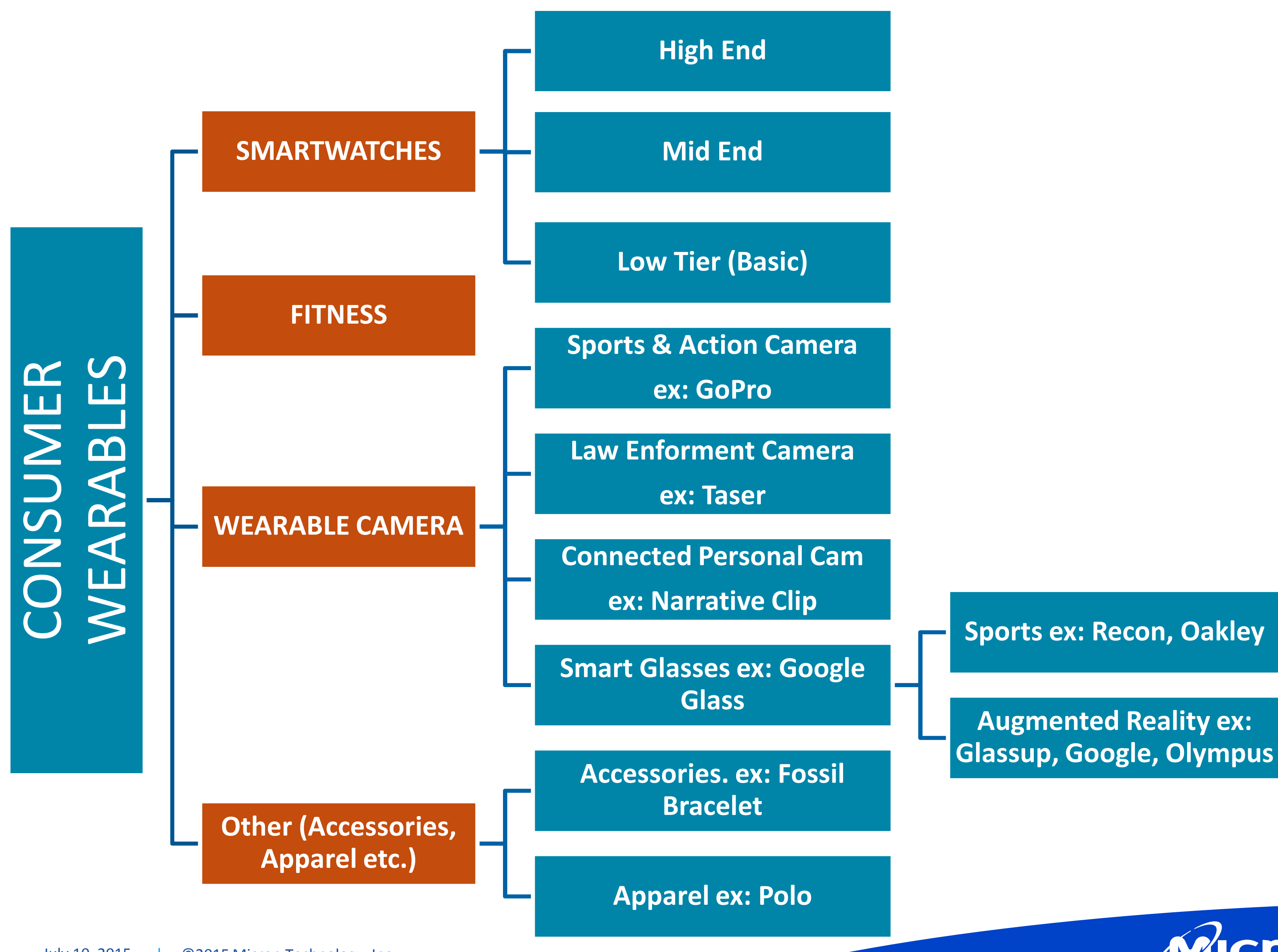
Wearables: A Diverse Market



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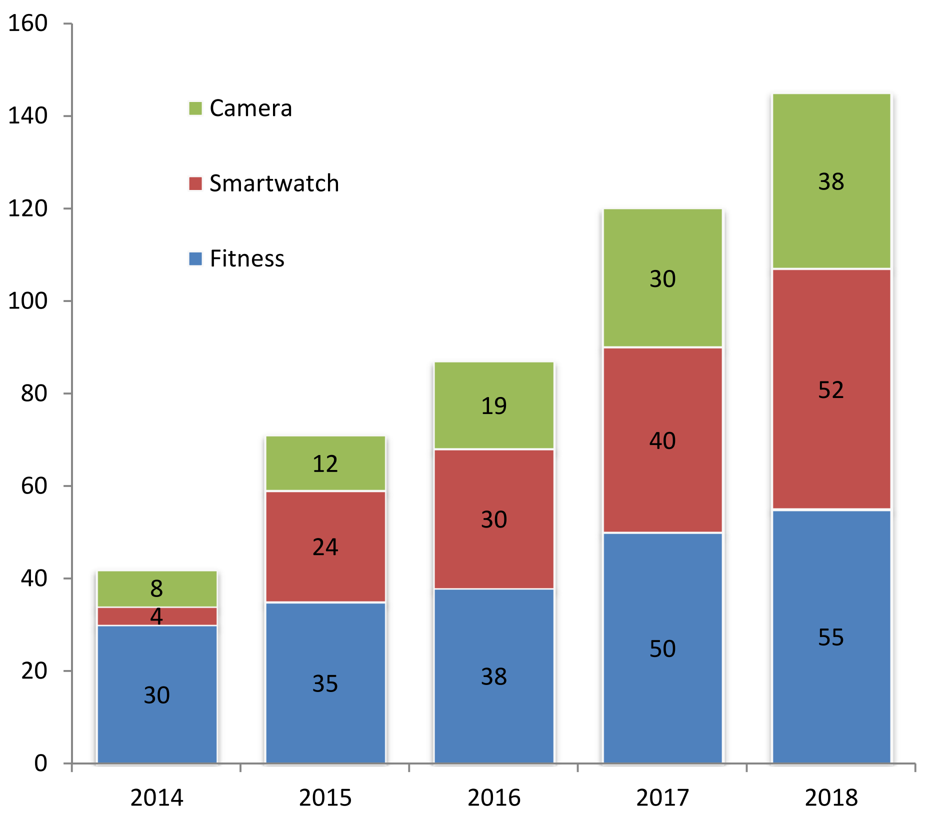
Consumer Wearable Market Forecast



- Wearable Application CAGR = 67%
  - Fit-band market acceptance high, Smart-watch and wearable camera ramping.

Source: Citi, Deloitte, Business Insider, iSuppli

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Early Market Leaders in Wearable

	Company	Category	Near Term Growth	Growth Trends[1]
Smart watches	adidas, SONY	High End (>$300)	↑ (green)	• Apple watch • Initial high growth in smart-watch
	SAMSUNG, LG, CASIO, pebble	Mid ($150-$300)	↑ (green)	• Many fast followers • Less integrated high quality solutions
	mi, ASUS, GARMIN	Low End (<$150)	↑ (yellow)	• Huge potential in the long run • Likely to be supplanted by high-end fitness devices
Wearable Cameras	GoPro, GARMIN, SONY, Polaroid	Action Camera	↑ (green)	• 4K video in small form factor • Bridging gap between high end DSLR and smartphone camera
	recon INSTRUMENTS, EPSON, Google, pivothead	Smart Glasses	↑ (yellow)	• Augmented reality and gaming are biggest drivers • High cost a barrier today
Fitness Devices	fitbit, BASIS, GARMIN	Fitness Bands	↑ (green)	• Likely to continue growing • Some of these might evolve in smart watch companies
Othes	JAWBONE, LECHAL, FOSSIL, RALPH LAUREN	Accessories + Apparel	↑ (red)	• Very early market • Most growth expected in high end accessories and apparel but low memory content

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Source: EBU Marketing Assessment

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General Architecture

Wearable Systems Architecture

Basic Architecture	Mid Architecture	High-end Architecture
Embedded OS		Rich OS
Always On ↔ Interconnect ↔ FLASH, ROM, SRAM	Apps CPU, Always On, GPU, Display Processor, Video Processor ↔ Interconnect ↔ FLASH, ROM, SRAM, DMC	Higher Performance Apps. CPU, Always On, GPU, Display Processor, Video Processor ↔ Interconnect ↔ ROM, SRAM, DMC
Memory integrated in MCU, trends include adding external NOR for logging	Generally memory in MCU with external NOR . Trends show Increasing external NOR densities	Generally external MCP, eMCP, ePOP (4GB Flash+ 4Gb LPDDR2)

ARM

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Memory Options for Fitness Tracker

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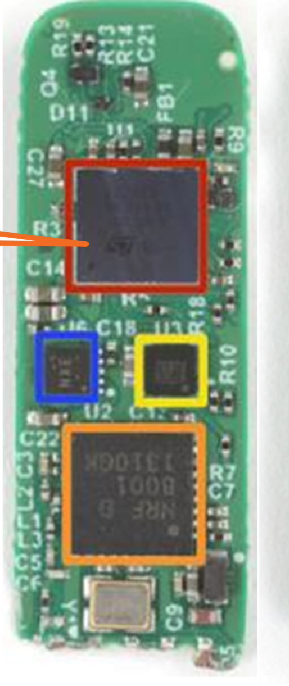
Fitbit Flex Fitness Tracker



32KB Flash, 16KB SRAM

- The motherboard flexes to show us what it's repping:
  - STMicroelectronics 32L151C6 Ultra Low Power ARM Cortex M3 Microcontroller
  - Nordic Semiconductor nRF8001 Bluetooth Low Energy Connectivity IC
  - Our best guess is that this is the accelerometer IC
  - Charger IC: TI BQ24040

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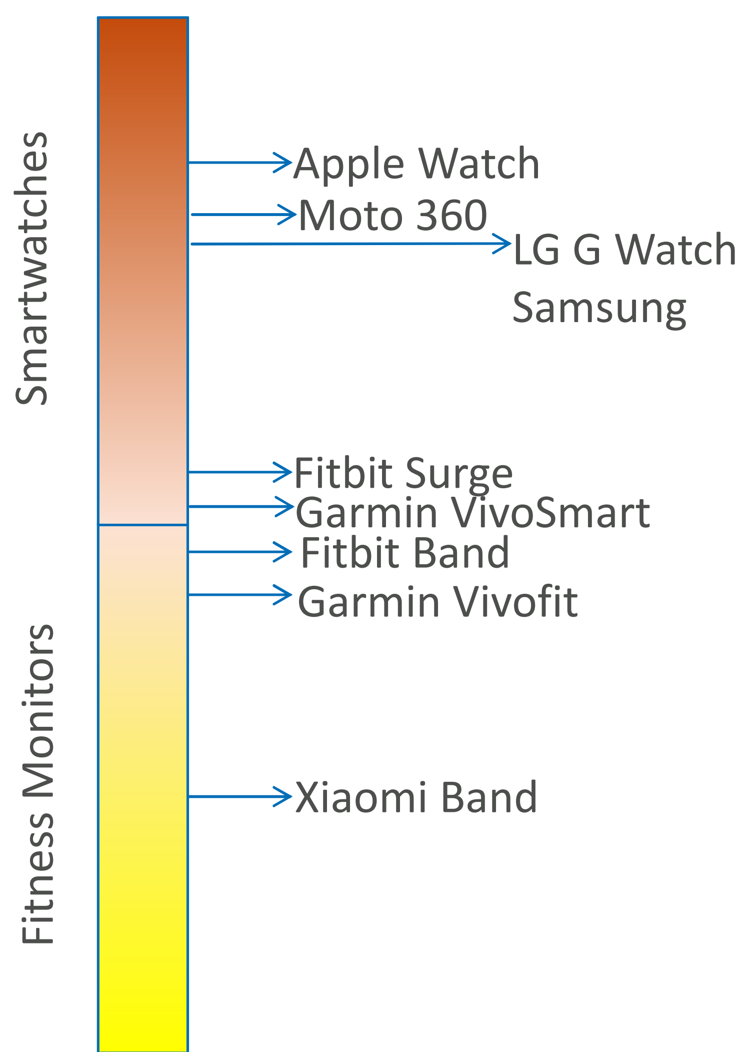
* Source: iFixit

Product Differentiation Driving Memory Needs



- Upward movement from smart bands to watches
  - Memory shift from Internal MCU memory to Small Density External memory
  - Ex: SPI NOR, SPI NAND, PSRAM MCP
- Smartwatches getting sleek and smarter
  - Memory shift towards more compact solution(package) and low power consumption
  - Ex: eMCP, ePoP

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Recommended Packages for Fitness Trackers

Package	RAM	FLASH
CSP	-	SPI NOR
DFN	-	SPI NAND

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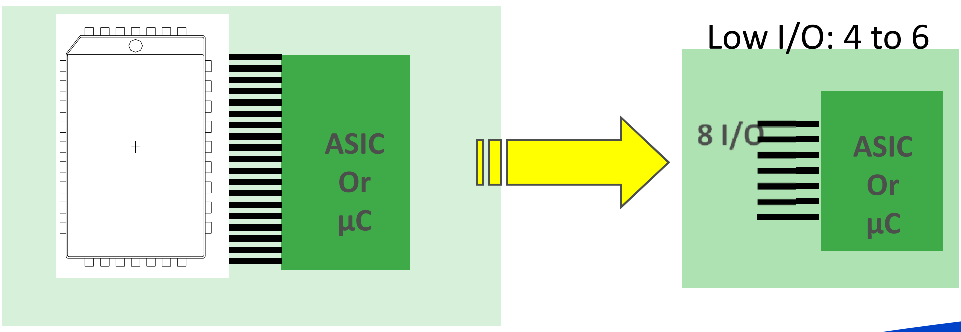
Technology Overview: Serial Peripheral Interface (SPI)

- Serial Interface – Just Simple and Small
  - Lower controller cost through low pin-count
    - 4 signals for SPI
    - 6 signals for Quad-I/O
  - Reduce board space and layers via small packages
    - 8-pin SOIC or 8-pad DFNs
    - Space-saving WLCSP available too
  - Simplify software development through standard commands and features
- Performance
  - Improved data throughput by 4x with no package change with multi I/O: Quad interface
  - Increasing clock frequency to over 100MHz is getting read speed close to parallel transfer rates

From Parallel NVM to Serial NVM



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SPI NAND: Simple and Small for Mid-Density Needs

- Applications adopting SPI NAND:
  - Wearables (1-2Gb)
  - DTV (1-4 Gb)
  - STB (2Gb)
  - Routers/Gateways (2-4 Gb)
- Drivers for adoption:
  - Competitive pricing
  - Low pin count for simpler design
  - Small size for small form factor design
  - 5 year data retention
  - Micron SPI NAND compatible with SPI NOR boot up

SPI NOR: Simple and Small for Low-Density Needs

- Applications adopting SPI NOR:
  - Home gateway/automation (4M..16Mb)
  - Wearable (8Mb … 128Mb)
  - DTV (32M.. 512Mb)
  - Set-Top Box (32M..2Gb)
- Drivers for adoption:
  - Smallest industry package with DFN down to 4x3 mm and WLCSP
  - Simple software management
  - 125 degree with AEQ100 certification
  - Instant read performance up to 80MB /sec
  - 10 year data retention
  - Advanced Security with RPMC

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Memory Options for Smart Watch

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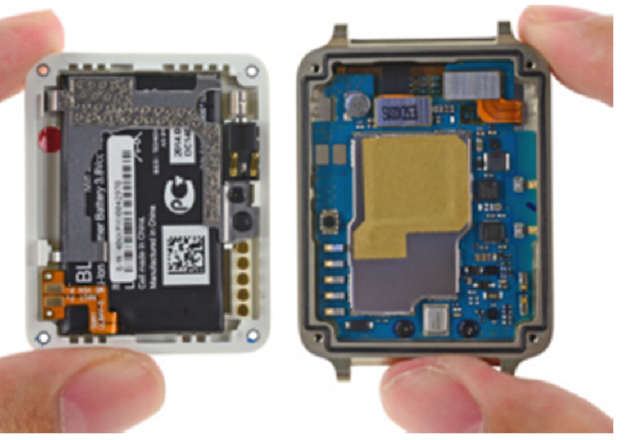
LG G Watch Tear Down

- Chips up front:
  - SK Hynix H9TU32A4GDMC 512 MB DRAM—the Qualcomm APQ8026 System on Chip is layered beneath
  - Qualcomm PM8226 power management IC
  - InvenSense MPU-6515 6-axis accelerometer + gyroscope
  - InvenSense INMP441 Microphone
  - 2407 DSH 12EDF

ePOP (4GB e.MMC + 4Gb LPDDR2)

- Not much back here:
  - Synaptics S3402B ClearPad 3400 series touchscreen controller
  - Broadcom BCM20715 Bluetooth 4.0 controller



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* Source: iFixit

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Apple Watch

S1 Decapped Apple Watch

Broadcom WiFi/BT/ NFC/FM BCM43342

AMS NFC signal booster AS3923

NXP NFC controller

STM Sensor Acc/gyro

Dialog PMU (D2238A) 338S00046

Elpida (top wire bonded) 4Gb SRAM memory F440AAC

Main processor (flip chip bottom)

APL 0778

Sandisk/Toshiba Flash memory 8GB

NXP

ADI Touch controller AD7149

IDT Wireless charger P9022

0 CM 1 2

4Gb LPDDR3 KGD

8GB e.MMC

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* Source: ABI Reserach

Recommended Packages for Smart Watches

Package	RAM	FLASH
Discrete	LPDDR 2	NAND
	LPDDR 3	e.MMC (NAND + uC)
	LPDDR 4	
MCP (Multi-Chip Package)	PSRAM + NOR	
	ePOP(e.MMC + LPDDR + POP Packaging)	
Die Only	Any of the discrete solutions above	

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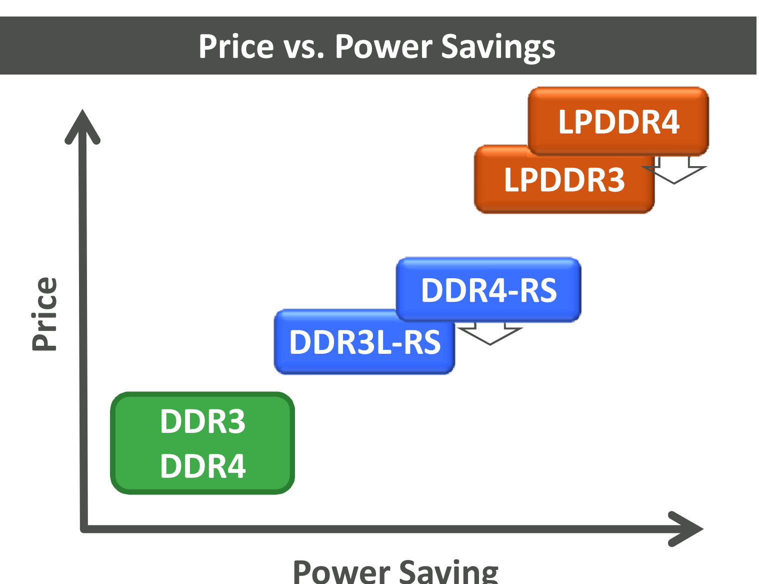
DRAM Solutions Value Proposition



Performance

Portability

Battery Life

DDR3

- Mainstream product optimized for cost and performance
- Target the 'value' Client and Ultrathin, embedded segments

DDR4

- Active power savings with drop from 1.35V to 1.2V
- Samples at enablers now
- Customer samples available **Now**

RS – DDR3L / DDR4

- **Extended battery** life while keeping cost competitive (IDD6 reduction)
- Backward compatible to DDR3/4 standard
- Target Ultrabooks™, Ultrathins, and Tablets
- DDR3L-RS in **mass production today** with a 10% premium over standard

LPDDR3 / LPDDR4

- Optimized for battery life and portability - **low power** is primary feature
- Increased cost due to chip size and product variety
- Target premium Ultrabooks™, Ultrathin laptops and tablets, smartphones

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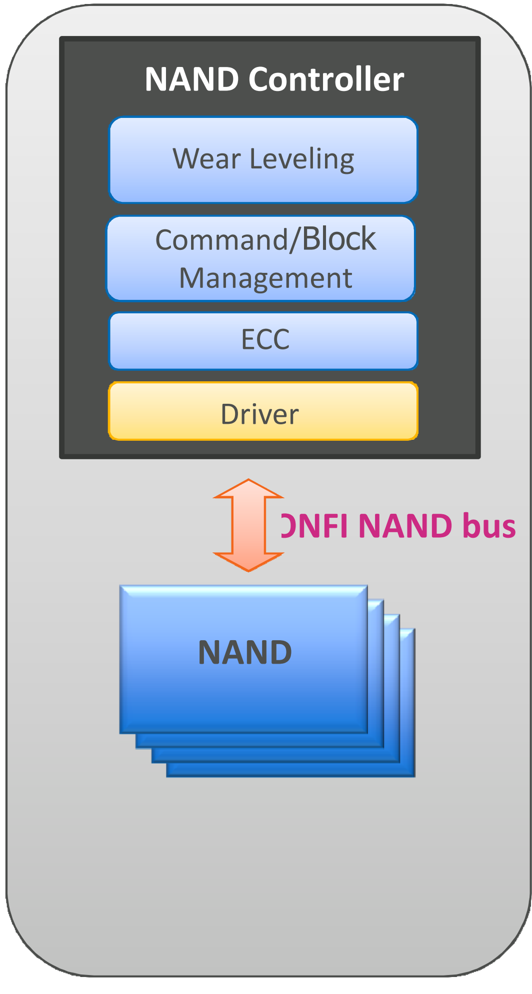
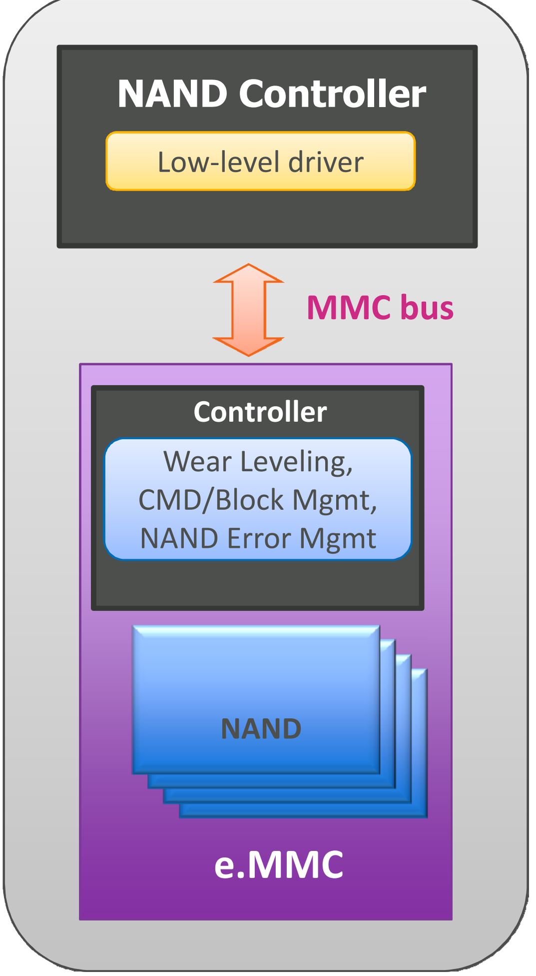
How the System Changes with e.MMC





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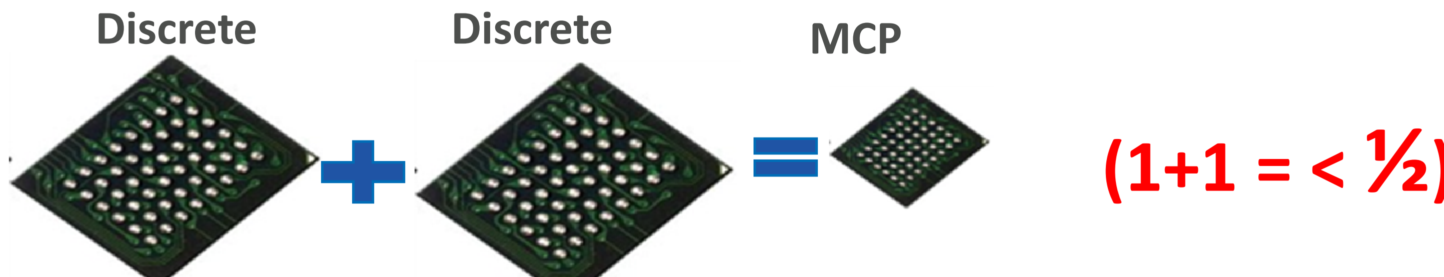
Multi Chip Package(MCP)

The MCP Advantage

- Major advantages of the MCP:
  - Contains at least two memory technologies (NVM Flash + Volatile RAM)
  - NOR + PSRAM Shared-bus: Low Ball Count/shared signals/power delivery
  - NAND or NOR + LPDDR1/2 Multi-bus: Separate Flash & RAM bus in single package
  - Reduces PCB board space vs multiple discrete packages
  - All MCP’s offered are Industry JEDEC Standards



Shared Pins, Reduced Ball Pitch, Smaller Package, Lower Cost

Look out for Well Established Ecosystem, Chip-set support, Mature silicon & Proven Manufacturing

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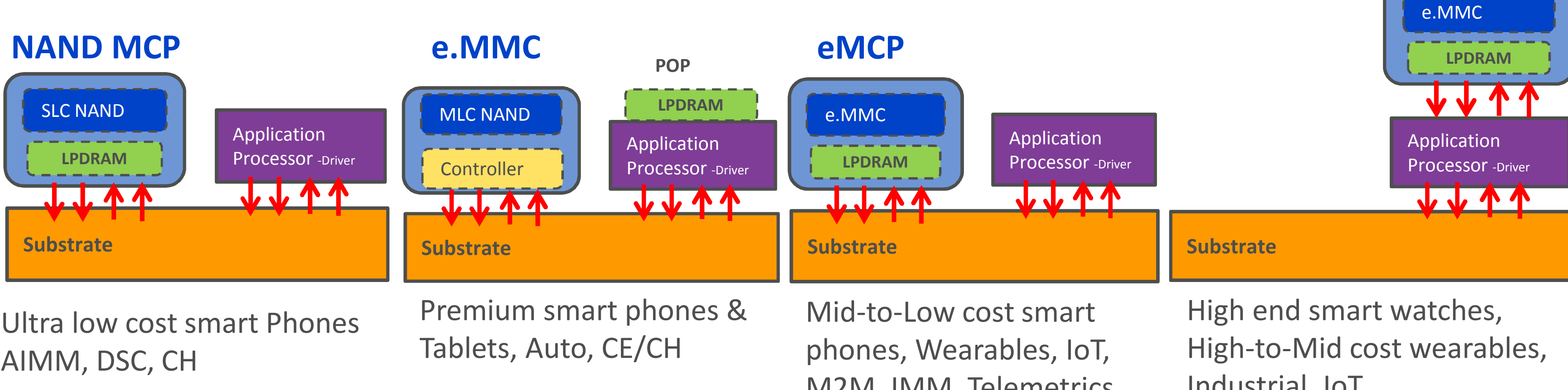
What is an eMCP/ePOP?

- ePOP is eMCP(e.MMC+LPDDR) in a PoP(Package on Package) design
- Benefits include…
  - 30-40% savings on board space through vertical stacking of several memory chips
  - Minimize bill of materials for simplified manufacturing and cost savings
  - High density, Low power consumption, shortest interconnections possible
  - Accelerated time to market through rapid integration of modules



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Memory Options for Wearable Camera

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GoPro Hero 3 Teardown

MCP
(4Gb LPDDR2 + 4Gb SLC NAND)

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*Source: iFixit

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Recommended Packages for Wearable Camera

Package	RAM	FLASH
MCP (Multi-Chip Package)	LPDDR + NAND	
	eMCP (LPDDR + e.MMC)	

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Comparison of NAND MCP and eMCP

		4Gb SLC NAND + 8Gb LPDDR3	4GB MLC e.MMC + 8Gb LPDDR3
Temperature Effect		60s NAND 10yr at 10K cycles. 1yr at 100K cycles [55C] 0.4yr at 10K cycles. [85C]	80s NAND 5yr at 300 cycles. 1yr at 3K cycles [55C] **~0.1yr at 300 cycles. [85C]**
Performance	Initialization	100us	**~1s(max)**
	Read/Write/Erase	At 50Mhz Clk (highest sustainable speeds) Read: 32MB/s Write: 20MB/s	At 52DDR on e.MMC single channel Read: 35MB/s Write: 11MB/s
	Latency(max)	600us (tprog max)	**150ms (max latency)**
Power Consumption	Voltage	Vcc- 1.8V	**Vcc - 3.3V Vccq - 1.8/3.3V**
	Current	Icc : Write/Erase - 25mA Read - 25mA	Icc/Iccq : Write/Erase - 35mA Read - 65mA
Dimensions(mm)		11.50x13.00x0.80	**11.50x13.00x1.00**

- While e.MMC has a superior price/bit over SLC NAND, there are some design considerations to consider when enabling e.MMC
  - e.MMC is only offered in 3.3V
  - SLC technology is more reliable at high temperatures
  - Performance is nearly the same, but initialization time and latency can be issues

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Recommended Packages for Wearables(Summary)

<table>
<tr><th>Application</th><th>Package</th><th>RAM</th><th>FLASH</th></tr>
<tr><td rowspan="3">Fitness Trackers</td><td rowspan="2">CSP</td><td>-</td><td>SPI NOR</td></tr>
<tr><td>-</td><td>SPI NAND</td></tr>
<tr><td>MCP (Multi-Chip Package)</td><td colspan="2">PSRAM + Flash</td></tr>
<tr><td rowspan="5">Smart Watch</td><td rowspan="3">Discrete</td><td>LPDDR 2</td><td>NAND</td></tr>
<tr><td>LPDDR 3</td><td>e.MMC (NAND + uC)</td></tr>
<tr><td>LPDDR 4</td><td></td></tr>
<tr><td>MCP (Multi-Chip Package)</td><td colspan="2">ePOP(e.MMC + LPDDR + POP Packaging)</td></tr>
<tr><td>Die Only</td><td colspan="2">Any of the discrete solutions above</td></tr>
<tr><td rowspan="2">Camera</td><td rowspan="2">MCP (Multi-Chip Package)</td><td colspan="2">LPDDR + NAND</td></tr>
<tr><td colspan="2">eMCP (LPDDR + e.MMC)</td></tr>
</table>

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Future Trends

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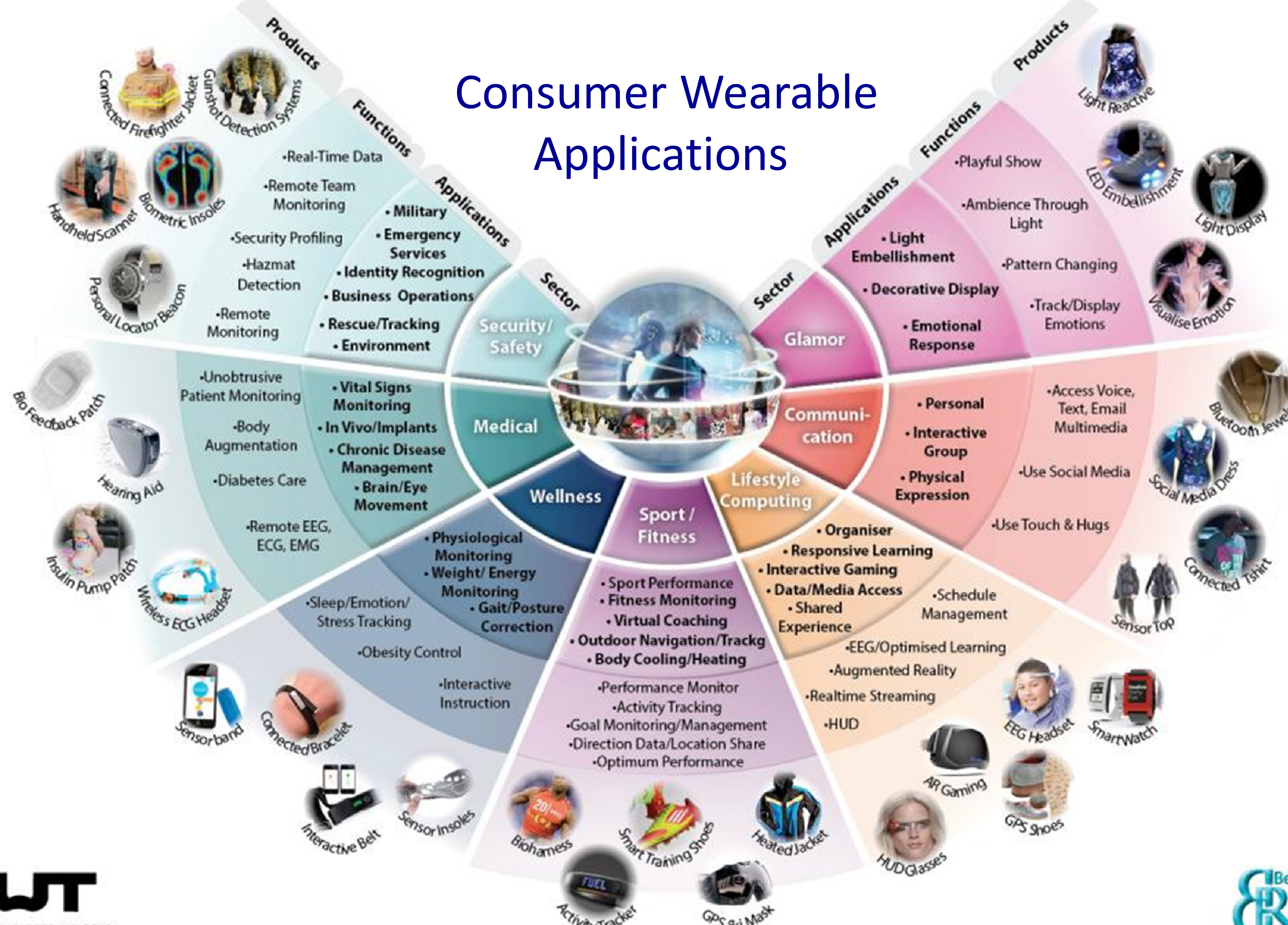
Consumer Wearable Applications



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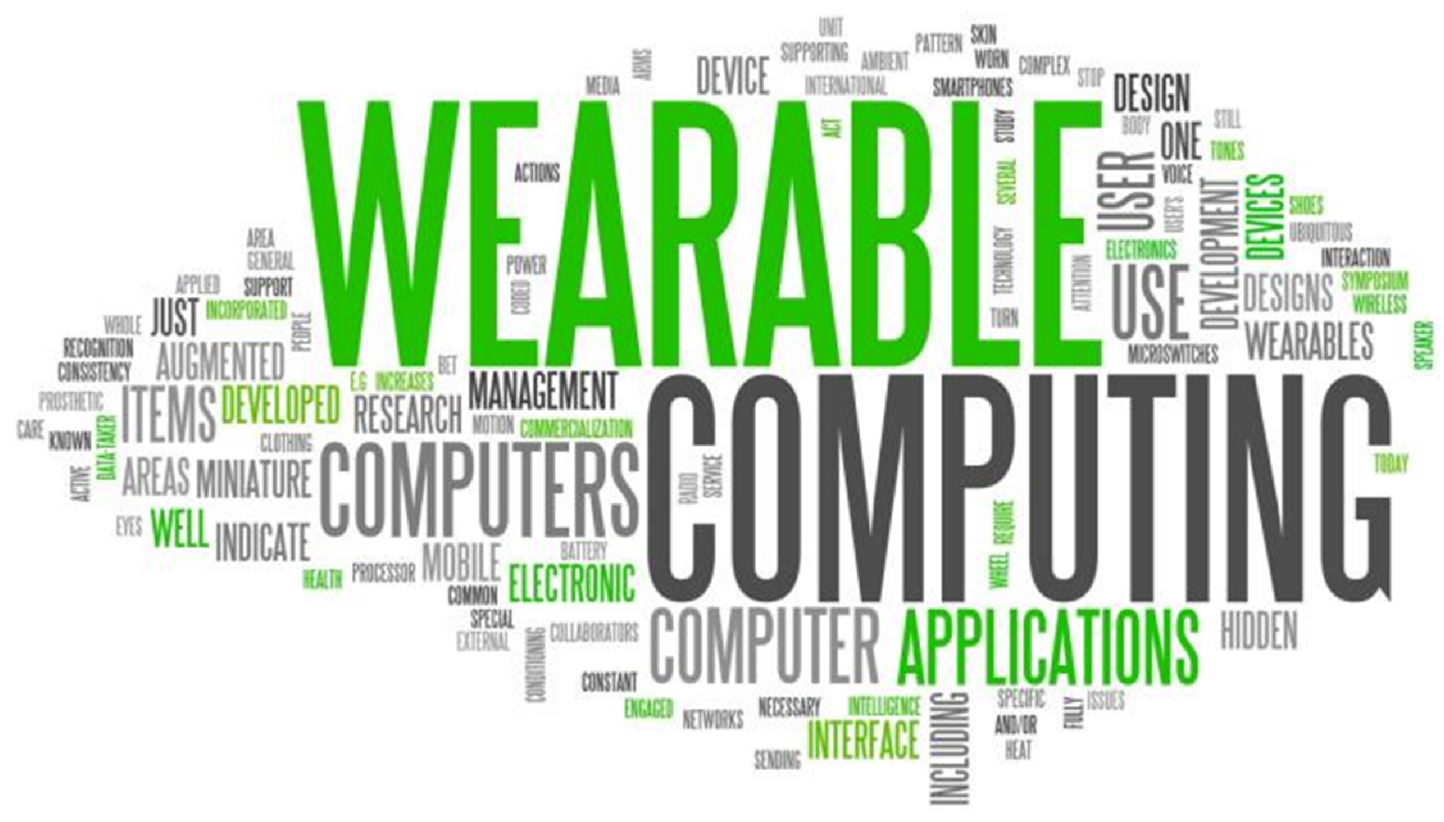
Wearables + Enterprise

- Salesforce Wear:
  - Launches a wearable platform to develop apps to improve how companies interact with their customers
- German Soccer team:
  - The winners of Soccer World Cup used Adidas Mio to track performance during training
- ProGloves:
  - Monitor and improve productivity in manufacturing
- Disney MagicBand:
  - RF bracelet that guests can use to enter parks, unlock hotel rooms, buy food/merchandise
- Sendrato(Winner at Wearable Technologies Conference, 2015):
  - Crowd engagement, access control, security and cost reduction are key factors for a successful event
- Virgin Atlantic Airways:
  - Partnered with air-transport specialist SITA to outfit employees at London Heathrow Airport with Google Glass to access information about first-class customers

Focus on customer service, productivity and safety



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