# Calculatoare Numerice (2)
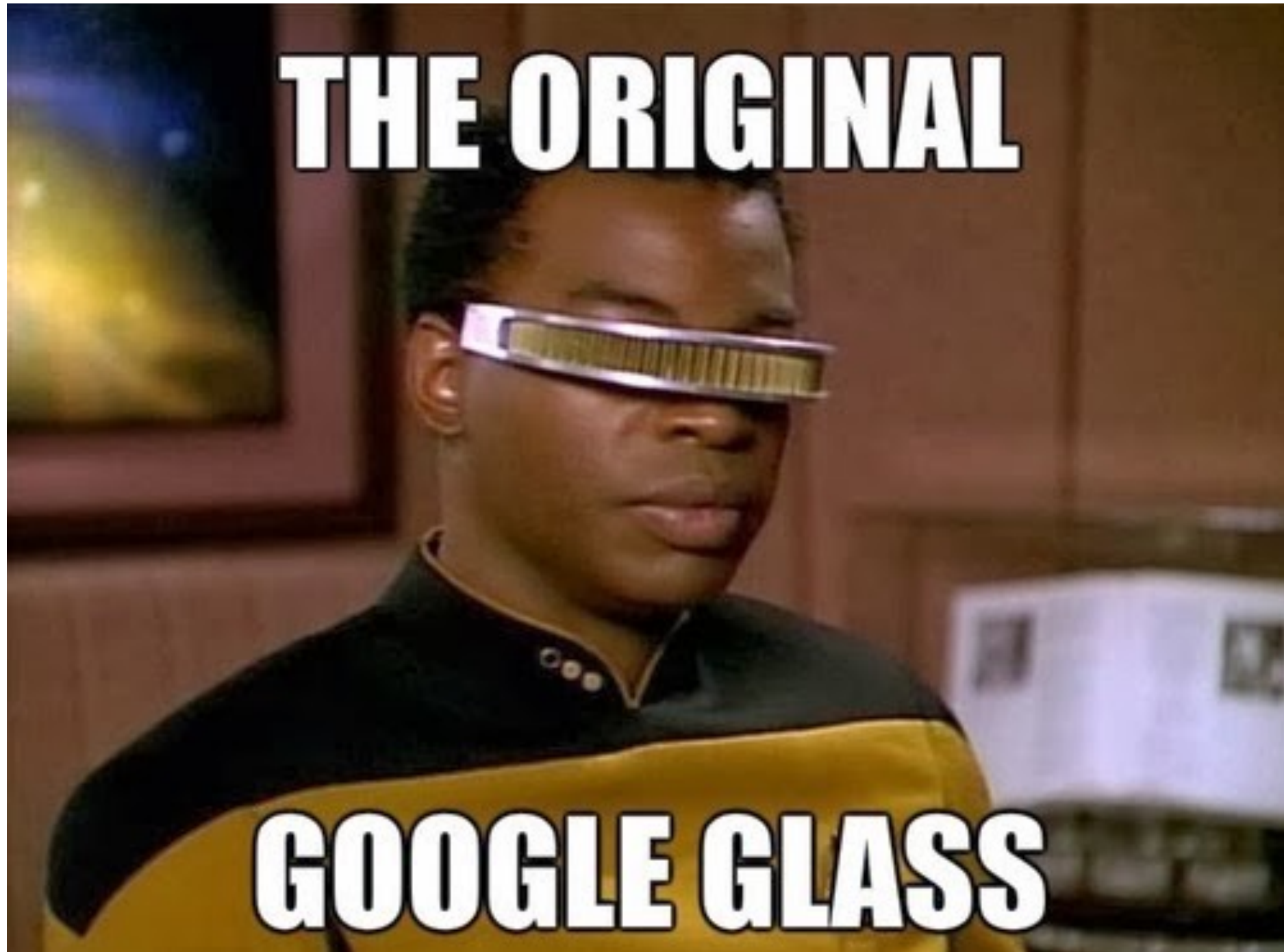
## Cursul 12

Wearable Computing

Facultatea de Automatică și Calculatoare
Universitatea Politehnica București
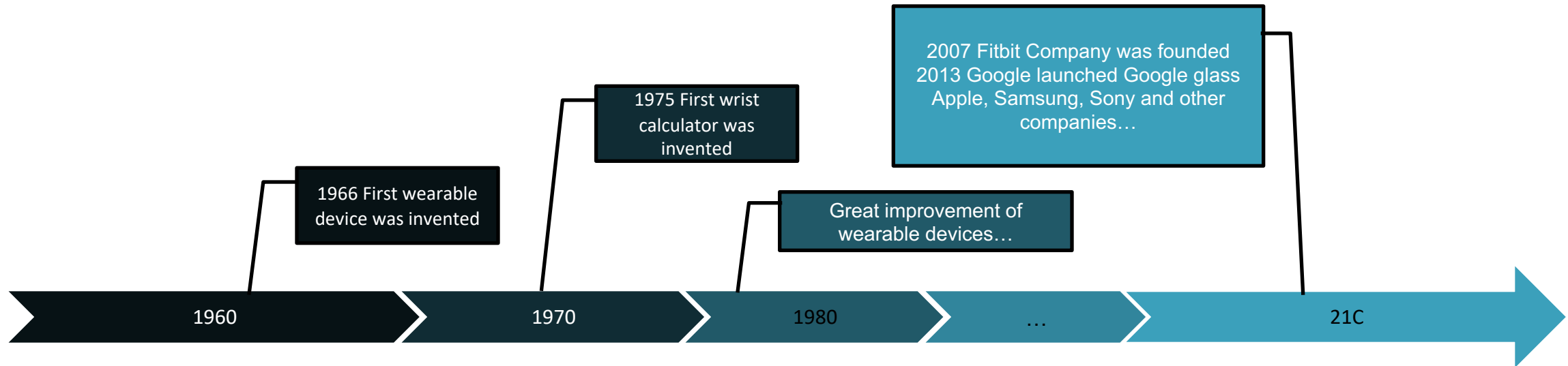
A wearable device is a computer
that is subsumed into the personal space of a user,
controlled by the user,
and has both operational and interactional constancy,
i.e., is always on and always accessible.

# Wearable History



1966 First wearable device was invented

1975 First wrist calculator was invented

Great improvement of wearable devices…

2007 Fitbit Company was founded
2013 Google launched Google glass
Apple, Samsung, Sony and other companies…

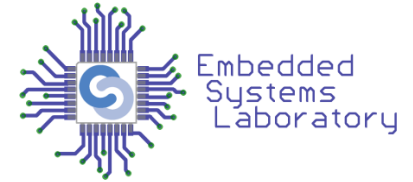1960 — 1970 — 1980 — … — 21C

## Forms

- Head-mounted (glass, helmet..)
- Body-dressed (coat, underwear, trousers..)
- Hand-worn (watch, bracelet, gloves..)
- Foot-worn (shoes, socks..)

## Functions

- Healthy living (sports wrist band, smart bracelet..)
- Information consulting (smart glass, smart watch..)
- Somatosensory Control (somatosensory controller..)

# Business case

- In 2013, investors poured $458 million into 49 wearable company deals ( *CB Insights* )

- $139 Billion Industry in 2022

- Expected to triple in size by 2030

- Major tech companies like Apple, Google, Samsung and Intel investing heavily in wearables, with non-tech giants like Nike, Under Armour, Adidas, Fossil, Timex etc.

# What makes wearables special?

- Used while the wearer is in motion
- Used while one or both hands are free or occupied with tasks
- Exist within the corporeal envelope of the user
  - Not merely attached to the body but becomes and integral part of the person's clothing
- Allows the user to maintain control
- (Should be) constantly available

# Some interesting issues



Operating Systems

Data Transmission

Energy Consumption

Security & Confidentiality

Data Management

Application Development Platform

# Popularity Example

- Pebble

- Kickstarter Campaign

- Seeks : $100K
- Raises : $10+ Million
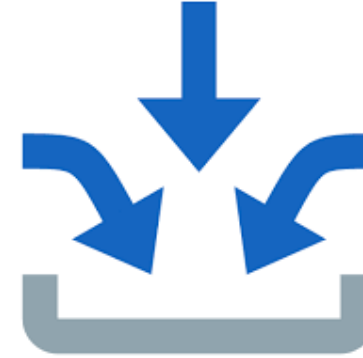
# Factors in Wearable Tech Today

- Faster and Cheaper Hardware

- Cloud Storage

- Location Data

- Quantified Self Activity

- Gaming Industry

- Visual & Voice Technology
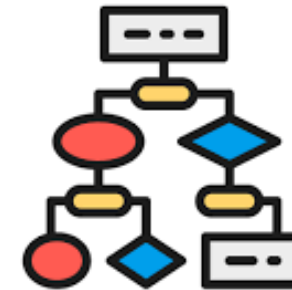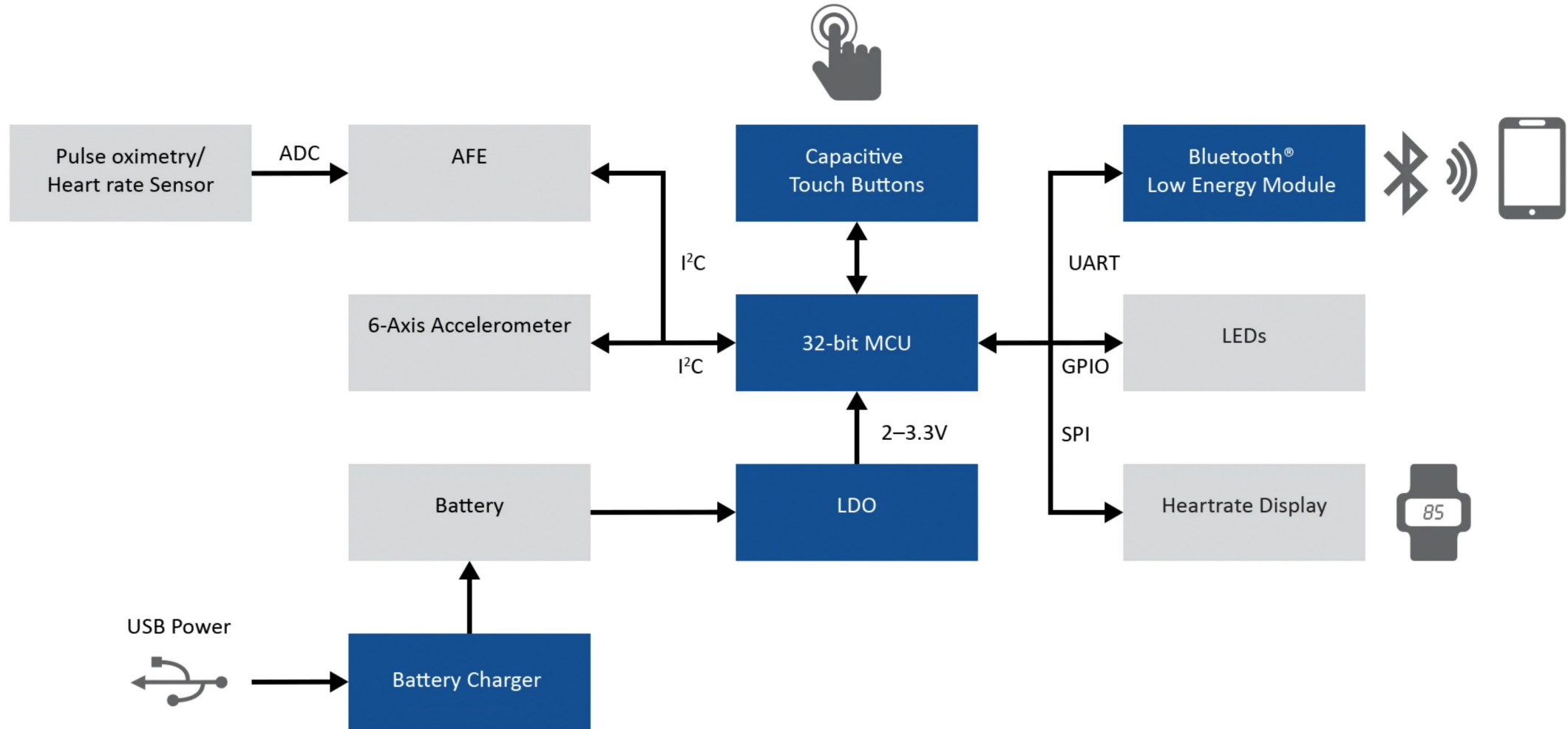
- User Experience

# State-of-the-art



Devices



Inputs



Applications



Algorithms

# Hardware

# What is (typically) inside a wearable?

# Apple Watch (Smartwatch)



## What Makes the Apple Watch Tick

**Apple Watch Sport 38mm**

| Component | Supplier | Estimated Cost |
|---|---|---|
| Touchscreen | TPK | |
| Display module | Analog Devices | $20.50 |
| Force touch sensor | | |
| Loudspeaker | | |
| Taptic engine | | |
| Battery | | $0.80 |
| Processor | Apple | $10.20 |
| Memory | Toshiba/Micron | $7.20 |
| Wireless charging coil | | |
| Bluetooth antenna | | |
| Aluminum housing | | |
| Digital crown | | $16.50 |
| Side button | | |
| Watch strap | | |
| Other materials | | $26.00 |
| Labor | | $2.50 |
| **TOTAL** | | **$83.70** |
| **RETAIL PRICE** | | **$349** |

### Materials and labor as a share of retail price

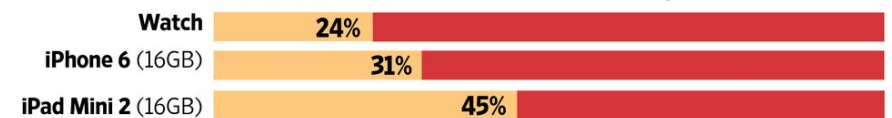| | |
|---|---|
| **Watch** | 24% |
| **iPhone 6** (16GB) | 31% |
| **iPad Mini 2** (16GB) | 45% |

Note: Cost analysis excludes logistics, manufacturing, software and IP expenses.

Source and photo: IHS Technology

THE WALL STREET JOURNAL.

# Apple Watch

# Apple Watch – main board



Bosch Gyro &
Accelerometer

STMicro ST33G1M2
MCU

USI 339M00034
Qualcomm
WTR3925 RF
Transceiver

Avago AFEM-8069
Front-End Module

Qualcomm
QFE3100
Envelope Tracker

Skyworks
SKY78108
PAM

Tech Insights



Apple Application
Processor with SK Hynix
LPDDR4 SDRAM

Broadcom BCM15920
Custom Sensing ASIC

Broadcom BCM59356
Wireless Charging
Power Management
Unit

Apple 338S00348 W2
chip (likely)

Toshiba NAND Flash

Qualcomm MDM9635M
LTE Modem with
Samsung K4P1G324EH
SDRAM

Apple / Dialog PMIC

Qualcomm PMD9645 PMIC

Tech Insights

https://www.techinsights.com/blog/apple-watch-series-3-teardown

# Jawbone (Activity Monitor)



MotionX®
Powered

**RECHARGEABLE BATTERY**
Up to 10 days of use on a single charge.

**VIBRATION MOTOR**
Powers your silent alarm clock & reminds you to move.

**PRECISION MOTION SENSOR**
Accurately tracks your movement and sleep activity.

**3.5MM PLUG**
Syncs your band with the app on your phone.

**SWEAT-PROOF & WATER-RESISTANT***
Wear the band while showering or working out.

* Water-resistant up to 1m.

# Fitbit Charge 5 (Fitness Tracker)

https://electronics360.globalspec.com/article/18433/techinsights-teardown-fitbit-charge-5-smart-band

# Fitbit Charge 5 – main board

- 1.02 inch OLED touchscreen
- ARM M-4 microprocessor
- Heart rate monitor and sensor

- TI AFE for heart rate monitor and bio-sensor
- TI's load switch, LDO regulator, haptic driver & 600 mA step-down converter
- Zinitix's DC-DC controller
- ST Microelectronics' 300 mA LDO regulator, three-axis MEMS accelerometer
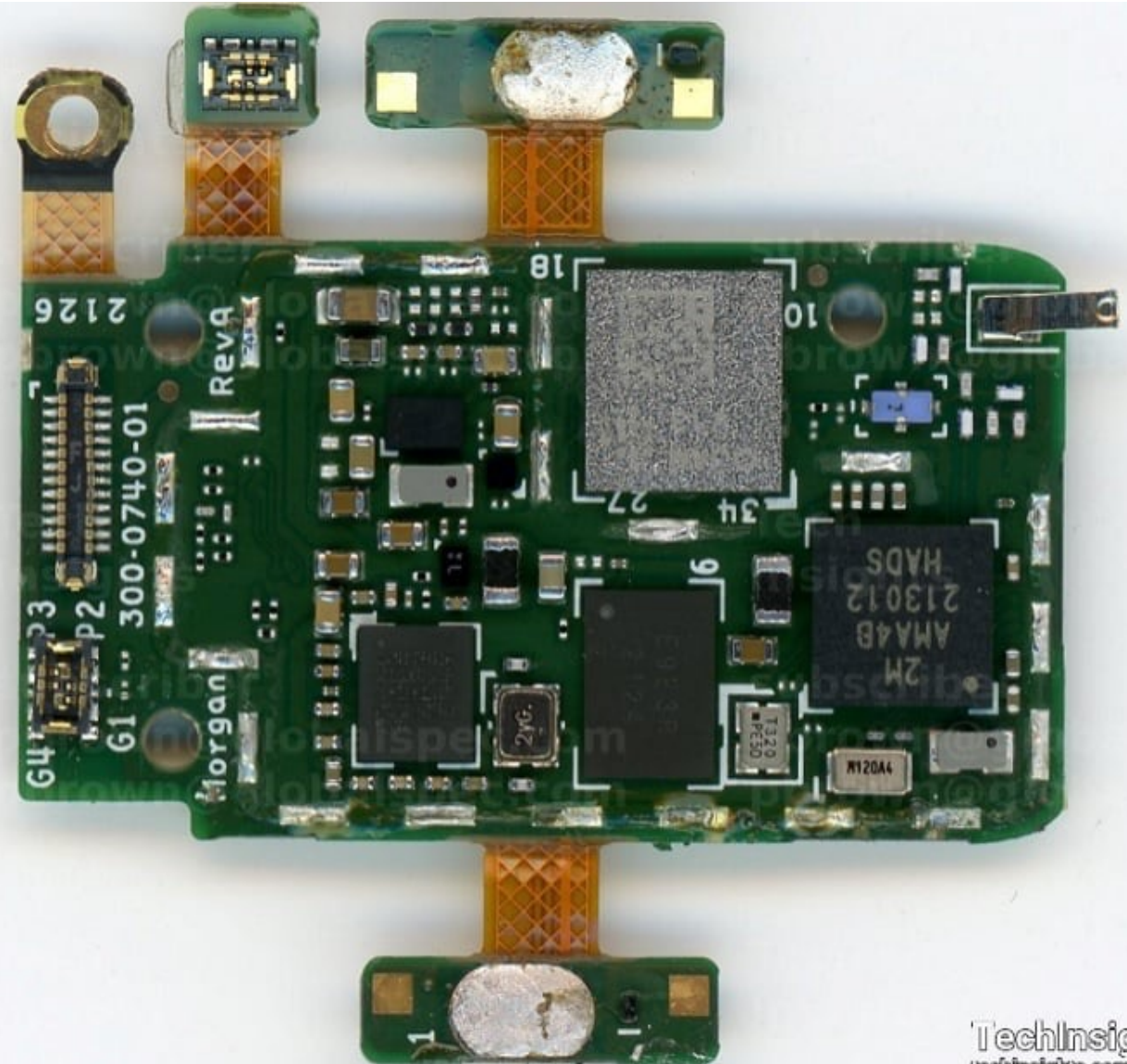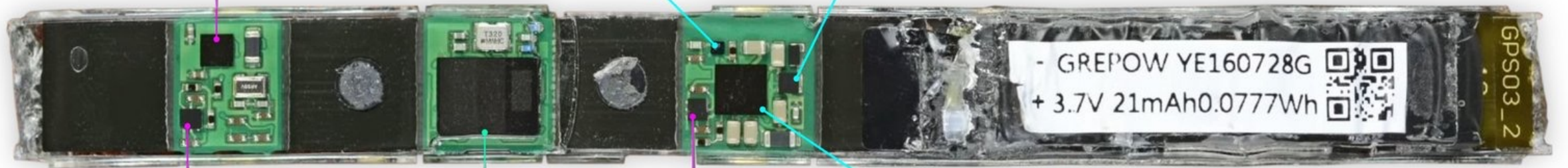
# Oura (Smart Ring)

# Oura (Smart Ring)



Unknown
*Rohm (?)*
Accelerometer/Gyroscope

ŌURA
SIZE 12

Unknown
*Unknown*
Operational Amplifier (?)

Unknown
*Unknown*
Battery Fuel Gauge IC (?)

Unknown
*Unknown*
Wireless Charging IC (?)

- GREPOW YE160728G
+ 3.7V 21mAh0.0777Wh

GPS03_2

Unknown
*Unknown*
IR LED Driver (?)

CY8C6336BZI (?)
*Infineon*
PSoC 6 MCU with BLE
Connectivity

Unknown
*Unknown*
IR LED Driver (?)

BQ25155 (?)
*Texas Instruments*
Battery Management IC

# Apple AirPods (Smart Headphones)

# Apple AirPods (Smart Headphones)

- Apple 343S00289 (likely Apple's new H1 chip)
- Dialog Semiconductor (Formerly Adesto) AT25SL128 128 Mb serial flash memory
- Apple 338S00420 (likely a low-power stereo audio codec)
- Bosch Sensortec BMA280 3-axis accelerometer (likely)



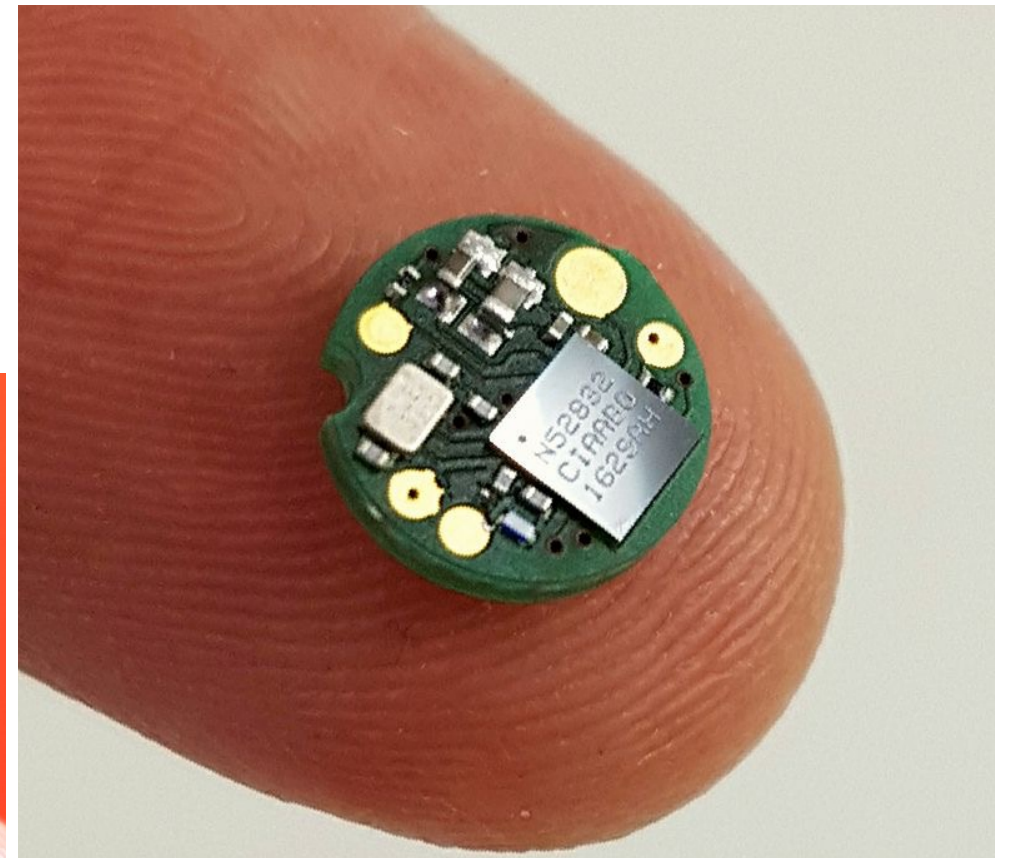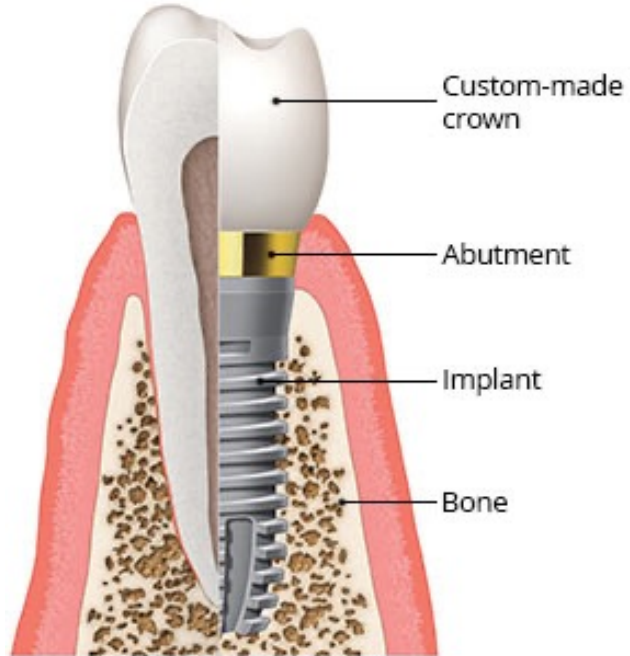https://www.ifixit.com/Teardown/AirPods+2+Teardown/121471

# Apple AirPods (Smart Headphones)

- 93mWh battery
- T 8 36 (likely STMicroelectronics inertial sensor)



https://www.ifixit.com/Teardown/AirPods+2+Teardown/121471

# Microsal (Smart Dental Implant)



Custom-made crown

Abutment

Implant

Bone

# Software

# watchOS

- Released 2015 exclusively for Apple Watch
- Limited open-source components
- WatchKIT API for developer use
- UNIX-like, slimmed down version of iOS
- Mostly closed ecosystem

apple.com/watchos/watchos-9

# Tizen OS

- Open-source OS

- Developed by Intel, Vodafone, Orange, Samsung

- Not exclusively for wearables

- Native HTML5 app support
  - HTML, CSS and JS

- Tizen for wearable OS
  - Light version developed by Samsung

- Low footprint
- Optimized battery life

tizen.org

# Wear OS

- Launched 2014, multiple HW platforms
  - 32-bit ARM, x86
- Open-source, closed source components
- Modified Linux kernel
- Multiple partners
  - LG, Asus, Samsung, Sony, Motorola

wearos.google.com

# NuttX

- Open-source RTOS
- Runs on a variety of HW platforms
  - From 8-bit AVR to 32-bit ARM
- UNIX-like, POSIX compliant
- Modified versions for trackers & watches
  - Fitbit, Xiaomi
- Growing user base and following

nuttx.apache.org

# Concerns

# Privacy

- Wearables might lead to an improved, better life
- Putting your body online might not always benefit you
- Give whole level characteristics to the service provider not each user level specific information
- Ensure visibility for what the user is sharing
- Human agency and responsibility need to be in the loop

# Security

- Wearable Device can be hacked and attacked wirelessly. Patients may die.

- Spoofing and altering are dangerous phenomena which can actually derail the whole purpose. May create panic.

- Side channel attack through power trace analysis is possible.

# Energy

- Main reason applications on wearables are limited
- A lot of R&D effort spent at all levels (HW+SW) to solve this issue
- Main trends
  - Processors become more and more efficient – smaller nm technologies for ICs
  - Software becomes more and more optimized – double-edged sword
  - New energy sources become attractive – wearable might end up powered by you
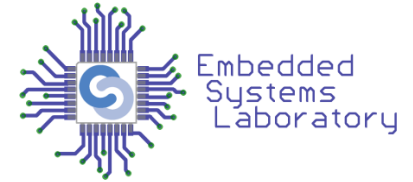
# Intrusion

- Too much personalization or assistance will repel users
- Users will be overwhelmed by the huge amount of data and can easily be panicked by misinterpreting any vital health data
- May curb creativity and reduce recall rate

# What comes next?

# Deeper Integration?

- Move towards seamless integration with other systems

- Market becomes more consolidated and standardized

- Advanced sensing – neural link, health assessment

- Metaverse?

# Edible Computers?

- "I expect to see edible computers pills, which will act like little medical monitors, downloading information about your state of health to a computer you wear."
  - Nicholas Negroponte, MIT Media Lab, 1999

- Technology already small enough to become implantable, only limitation is battery life