Smartwatch Architecture

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Overview

- What is it and Why is it Becoming Popular
- Timeline
- Common Smartwatch Specifications
- Basic to High-End Smartwatch Architectures
- Performance and Power Consumption Challenges
- Future Goals

What is it and Why is it Becoming Popular?

- Definitions
  - General: A wristwatch with a screen that does more than just tell you the time.
  - Modern: A wristwatch that indicates time and connects to the internet wirelessly.
- Purpose: less distraction

Smartwatch Timeline

- **1927:** Plus Four Wristlet Route Indicator
  - First and only use of a scroll map cartridge
- **1972:** Pulsar
  - First all-electric digital watch with LEDs
- **1982:** Seiko TV Watch
  - With an adapter and a receiver box, you could watch TV on it
- **1983:** Seiko Data-2000
  - Memos, calendar, and calculator
- **1985:** Sinclair FM Wristwatch Radio
  - Radio with a speaker
- **1995:** Seiko MessageWatch
  - Caller IDs, sport scores, stock prices, and weather forecasts

Smartwatch Timeline (continued)

- **1995:** Breitling Emergency Watch
  - Produces distress signals when in an emergency
- **1998:** Linux Wristwatch
  - First Linux Powered watch
  - Communicated wirelessly with PXs, cell phones and other wireless enabled devices
- **2002:** Fossil Palm Pilot
  - Address book, memo pad, to-do list, and a calculator with a stylus
- **2003:** Microsoft SPOT
  - FM radio, charged wirelessly
- **2003:** Garmin Forerunner
  - GPS sports watch, measured speed, distance, pace and calories burned
- **2012:** Nike+ Fuelband
  - Tracked your steps

Modern Smartwatches (2012-present)

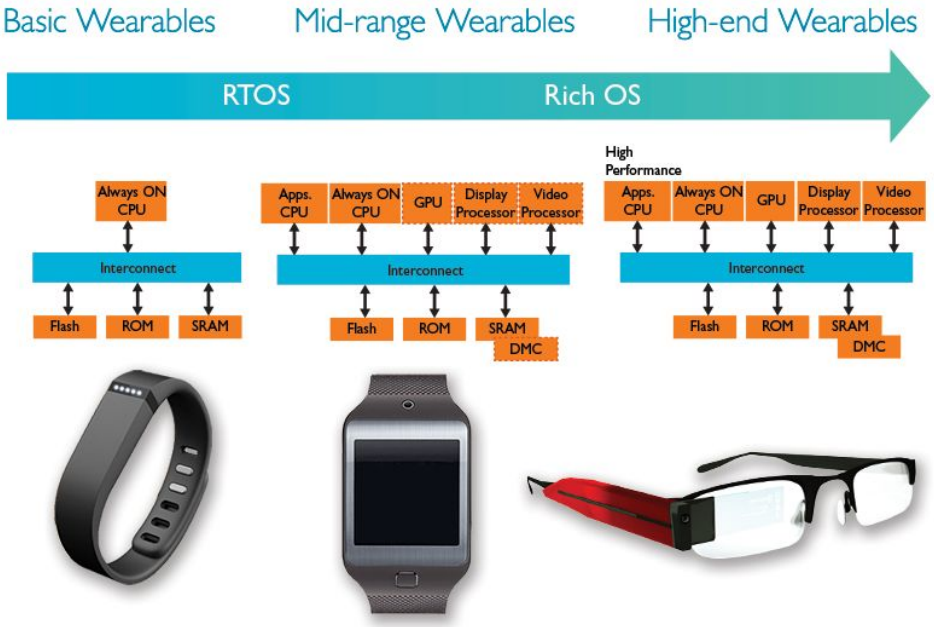
- **2012:** Sony SmartWatch
- **2013:** Pebble
- **2013:** Samsung Galaxy Gear
- **2014:** Samsung Gear Fit
- **2014:** Moto 360
- **2014:** Samsung Gear S
- **2015:** Apple Watch

- Features
  - Rich operating systems (OS)
  - Touchscreen
  - Paired with your smartphone via Bluetooth (BLE)
  - Receive notifications
    - Emails, text messages, missed calls, etc
  - Control your smartphone remotely
    - Play a specific song, take a picture, etc

Common Smartwatch Specifications

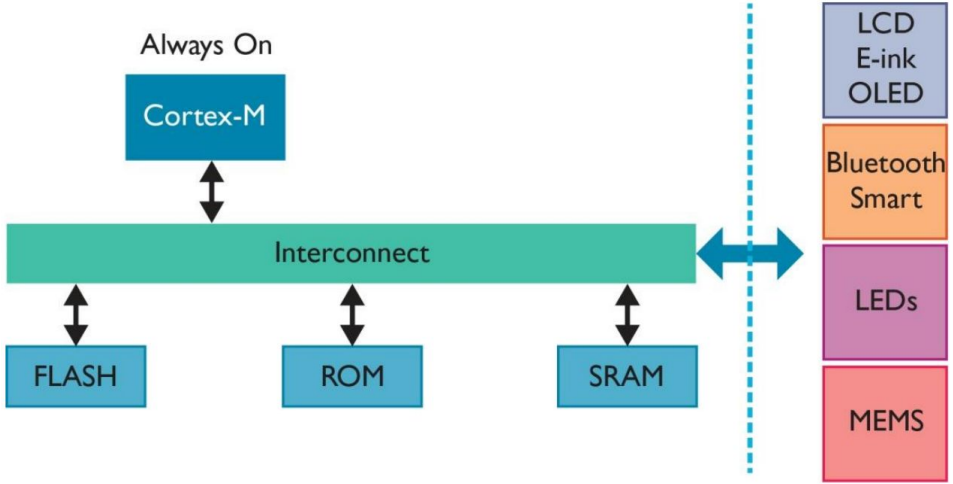
- Operating System (OS)
  - Common: Android Wear, Watch OS, Microsoft Band, Pebble OS
  - Others: Tizen, WebOS, Tencent OS (TOS+)
- CPU
  - Single or dual core
  - 80 MHz - 1.2 GHz
- RAM
  - 64 KB - 1 GB
- Display Type
  - LCD, OLED, AMOLED, White and Black/Color e-Ink
- Battery
  - Capacity: 130 - 420 mAh
  - Life per Charge: 18 Hours - 10 days
- Charging Type
  - Micro USB, Wireless, Magnetic
- Connectivity
  - Wi-Fi, Bluetooth 4.0+ (BLE), NFC, GPS
- Sensors
  - Heart Rate, Accelerometer, Gyroscope, Barometer, Ambient Light, Pedometer, etc

From Basic to High-End Smartwatch Architecture

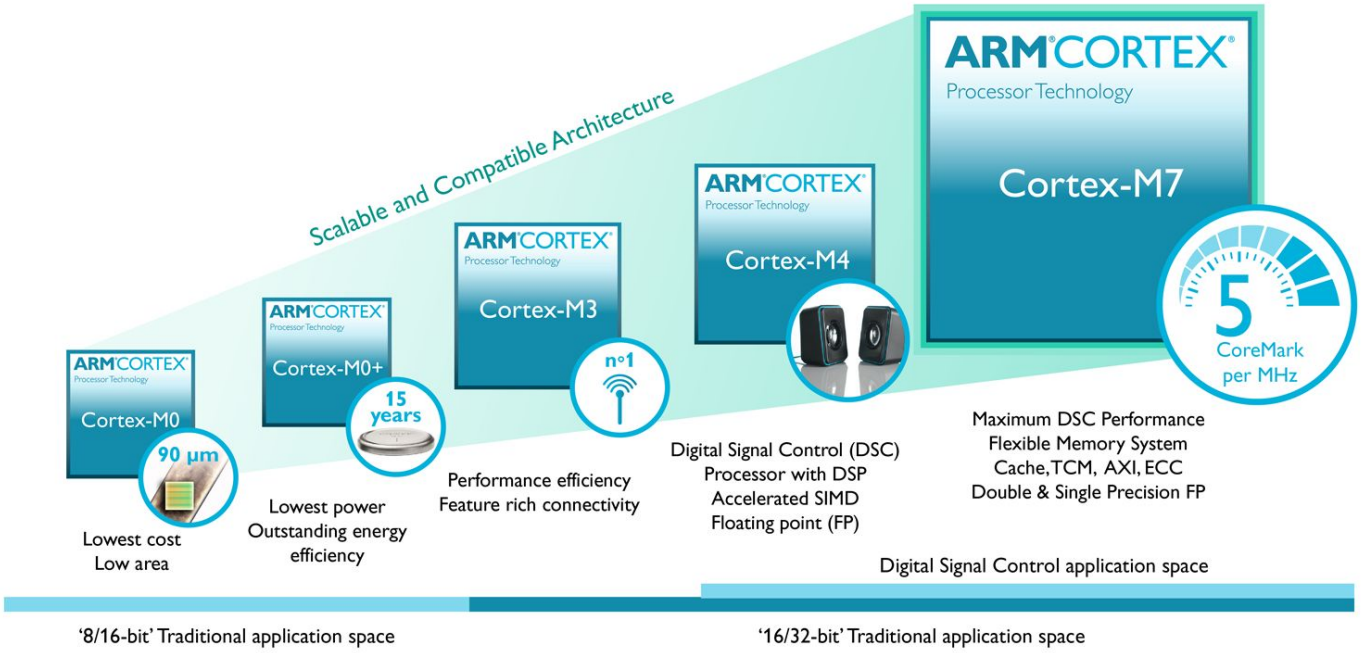


Basic Device Architecture

- On-chip memories
  - Flash, ROM, SRAM
- Simple Design
  - Activity/sports band
  - Simple watch
- Ultra-low power processor core
  - Cortex-M Series: industry standard
  - Always on sensor-fusion CPU
- Simple real-time operating system (RTOS)
  - Longer battery life



Cortex-M Series



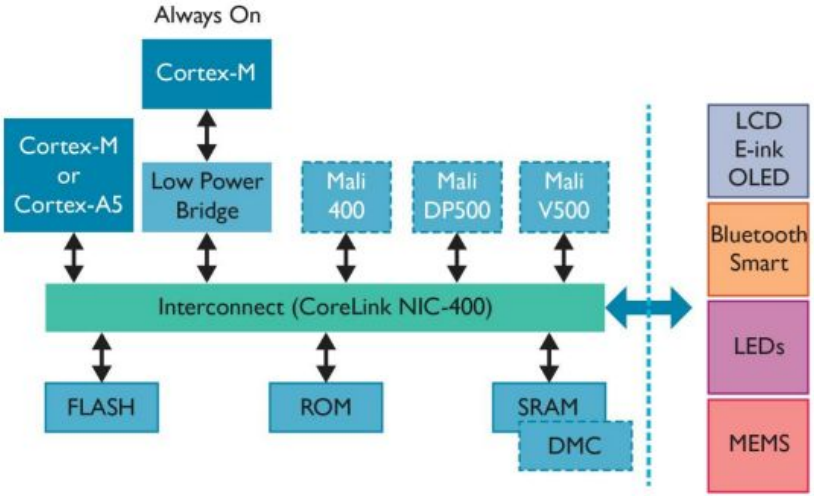
Cortex-M Series Power Consumption and Area

	90LP (7-track, typical 1.2v, 25C)		40G (9-track, typical 0.9v, 25C)	
	Dynamic power (µW/MHz)	Area mm^2	Dynamic power (µW/MHz)	Area mm^2
Cortex-M0	16	0.04	4	0.01
Cortex-M0+	9.8	0.035	3	0.009
Cortex-M3	32	0.12	7	0.03
Cortex-M4	33	0.17	8	0.04

Cortex-M Series Performance Benchmarks

	Dhrystone (official)	Dhrystone (max options)	CoreMark
	DMIPS/MHz	DMIPS/MHz	CoreMark/MHz
Cortex-M0	0.84	1.21	2.33
Cortex-M0+	0.94	1.31	2.42
Cortex-M3	1.25	1.89	3.32
Cortex-M4	1.25	1.95	3.40

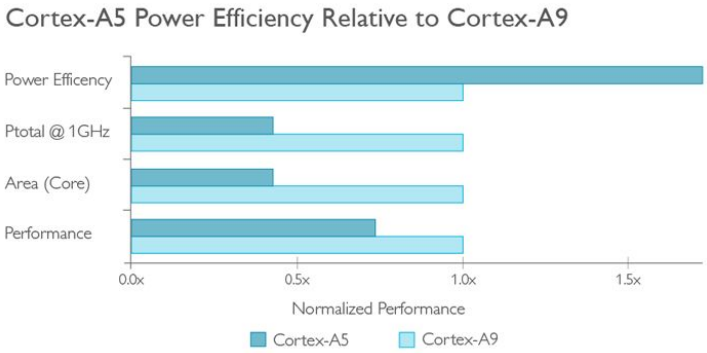
Mid-Range Device Architecture



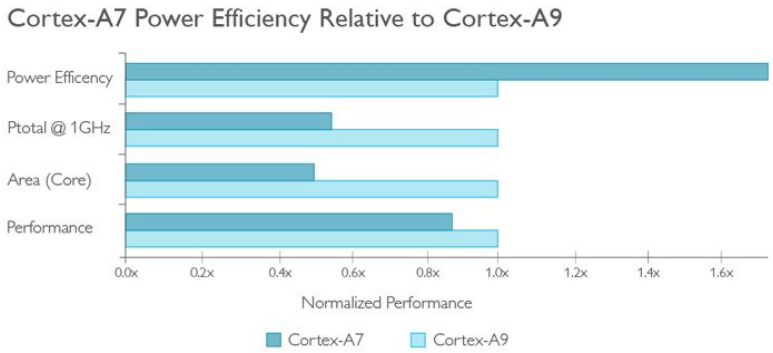
- Either an RTOS or a full OS
  - i.e., Linux
- Suitable for a smartwatch with advanced OS and a color display
- Dynamic memory controller (DMC)
  - Provides an interface to off-chip memories
- Single-core application processor
  - Cortex-A Series (A5 and A7)
  - Typically in sleep mode when not being used
- Mali Processors
  - Graphics, video, and display

Cortex-A5 vs. Cortex-A7

- Cortex-A5
  - Smallest and lowest power applications processor in the series
  - 8 stage in-order pipeline
  - Longer battery life
  - Less heat dissipation

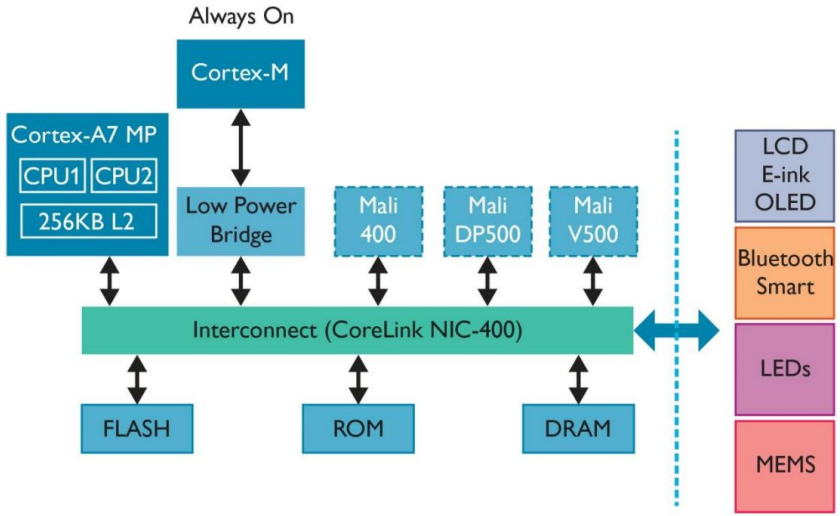


- Cortex-A7
  - Built on Cortex-A5's 8 stage pipeline
  - Integrated L2 cache
    - Low power
    - Lower transaction latencies
  - Improved branch predictions and memory system performance

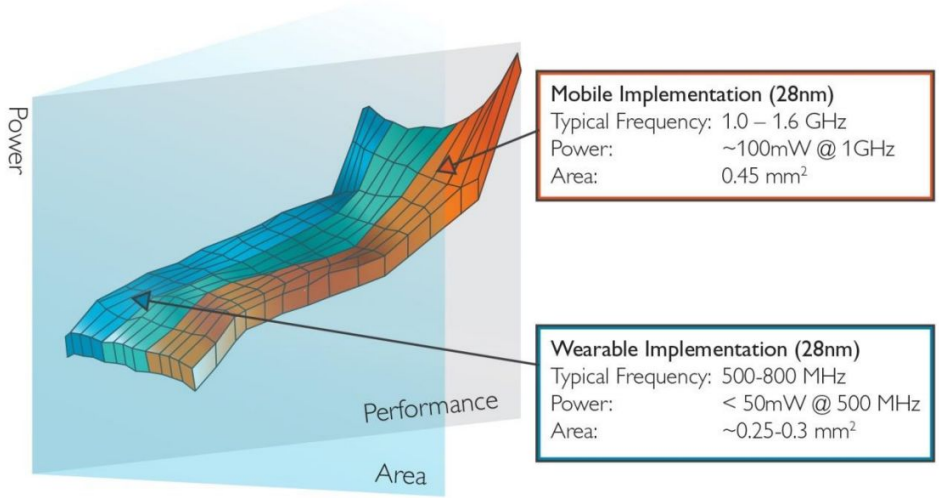


High-End Device Architecture

- Designed for high-end products
  - i.e., a smartwatch using Android Wear
- Dual-core multiprocessing application processor
  - Cortex-A7
    - Scalable performance
  - Energy-efficient L2 cache subsystem
- Low-power DDR memory



Performance and Power Consumption Challenges



- Power consumption: not optimized
- Memory caches: too large
  - Use more area and power
- Higher performance = more power consumed
  - 1-2 days of battery life
- Current approaches
  - Reduce standby power
    - Low-power modes
  - Reduce cache memory depending on the size of workloads
    - 32K L1 cache to 16K = less than 10% impact on performance
- Always a tradeoff between performance and power consumption

The Future of Smartwatches

- Fully integrated mobile phone technology
- Improved architecture
  - Smaller cache memory
  - Slower clock speeds
    - Lower frequency
  - Longer battery life
    - Slowly achieving 6-10 days
- More applications
  - Personal assistance
  - Medical/Health
  - Personal safety

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