TINY System Ultra-Low Power Sensor Hub for Always-on Context Features

MediaTek White Paper

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MediaTek's sensor hub solution, powered by the TINY Stem low power architecture, supports always-on context to efficiently perform motion/gesture detection, activity recognition, and context-aware computing. The cost-effective TINY System takes advantages of the SoC and advanced semiconductor manufacturing processes to provide high performance processor, large SRAM and more peripherals to satisfy rich context-aware applications with ultra-low power consumption.

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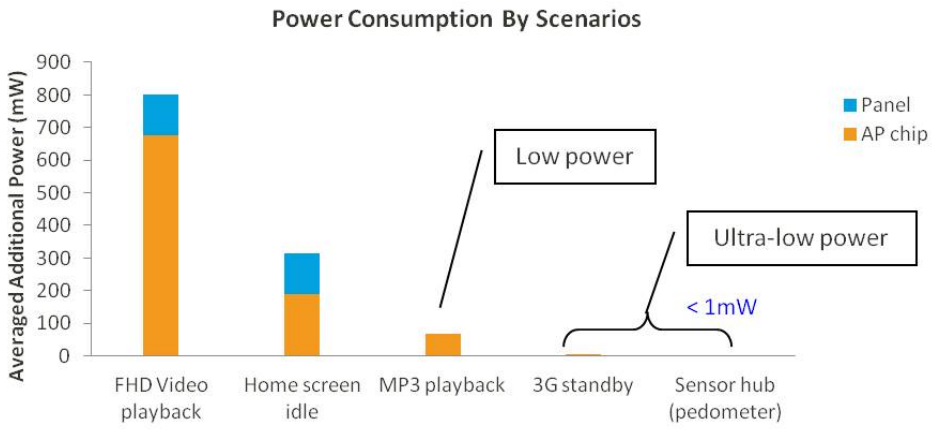
Introduction

Today increasingly more sensors are integrated into mobile and wearable devices to enrich the content and to enable new context-aware features. Sensor-generation raw data are used or computed to be meaningful context, such location, activity, or environment. The context-aware features can be used to create more application services and they are important elements for the development of intelligent devices. Indeed popular context-aware applications can predict the information that a user needs, or know the user location, what the user is doing, or which devices are nearby.

A key issue in designing sensor features is power consumption required to support always-on context. When additional power consumption for always-on context is less than 1mW, as seen in the MediaTek embedded sensor hub usage, the additional power consumption is minima—similar to that of 3G on standby. Assuming that the power consumption of a smartphone is 3000mAh and 100mA is consumed per hour, the phone can be used for 30 hours. With 1mW (~0.26mA at 3.8V battery side) additional power consumption for always-on context, the phone still can be used for nearly 30 hours. The impact of additional power consumption for always-on context is so minor that users may even not sense it.



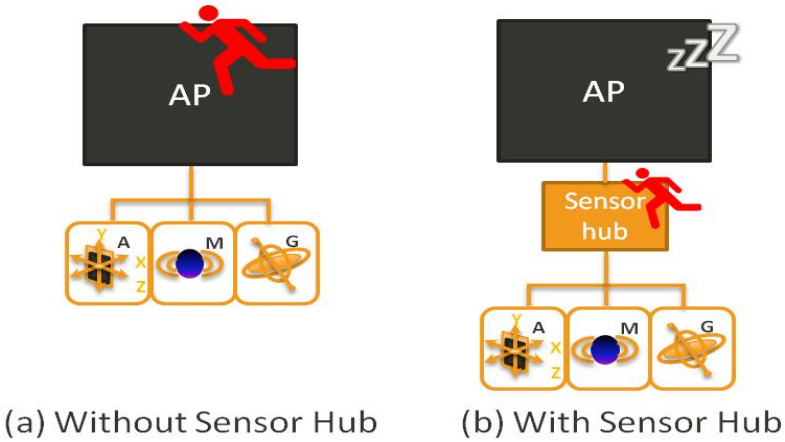


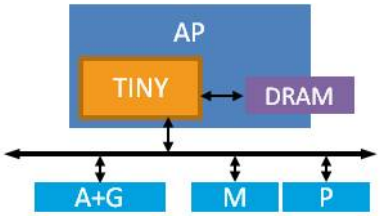
Figure 1. Application Processor without/with Sensor Hub Solutions

In traditional chip design architecture, the sensors are connected to the application processor (AP) directly. The application processor must wake up to receive sensor data, as shown in Figure 1(a), which results in high power consumption. The application processor power consumption increases significantly as the number of sensors increases. Indeed the AP will dominate the power consumption of mobile or wearable devices.

Already in the market are some solutions for always-on context with ultra low power consumption to avoid waking the application processor to receive sensor data. One solution is the *sensor hub*, a hardware system isolated from the application processor. Another is the *smart sensor*, a customized low power sensor. These solutions aim to let the application process wake up only when needed, and to help sensors process data without involving the application processor to save power, as shown in Figure 1(b) above.

The smart sensor solution usually has limited capabilities, so only few applications are supported. The sensor hub design is responsible for collecting or computing the sensor data generated by different sensors (e.g., Accelerometer (A), Magnetometer (M), Gyroscope (G), and Proximity (P)). The sensor hub solution usually has two types of designs—an external sensor hub and an *embedded* sensor hub. The external sensor hub is the more costly design. To address these cost and limited application support problems, MediaTek has introduced an *embedded sensor hub solution* powered on the low power

architecture of MediaTek's TINY System, a hardware/software integrated sub-system with many low-power optimization technologies.



MediaTek's Embedded Sensor Hub	
BOM Cost except AP	Low
Ultra-Low Power	Yes, even high loading
Peak Performance	CM4F (226 MHz)
SRAM	512KB
Fusion FIFO	YES

Figure 2. TINY System Features

MediaTek's TINY System Sensor Hub Solution

MediaTek's cost-effective ultra-low power embedded sensor hub design with always-on context features, shown in Figure 2 above, can reduce the application processor loading and provide outstanding performance. The TINY System combines a hardware/ software platform to mobile or wearable devices to process rich context-aware features and to sense data anytime or anywhere.

The TINY System is a very cost-effective solution on the market, as the customer can utilize the same PCB layout. BOM cost without an application processor is one major difference between the external sensor hub, smart sensor, and the TINY System. And the TINY System processor has higher computing capability, thereby allowing for more applications and functions. The system also has larger memory capacity. Indeed the TINY System can work well in both light and heavy workload conditions with very low active power. This excellent performance outshines external sensor hub solutions, which consume much higher computation power for the heavy workload.

In addition to the hardware optimization of sensor hub, MediaTek also introduces a sensor hub platform to provide software optimization for always-on context. Therefore, MediaTek aims to provide the best solution for the sensor hub product considering both of the hardware and software designs.

MediaTek TINY System Sensor Hub Design

The TINY System architecture contains four main components, including processor, SRAM, ultra-low power oscillator (OSC) and some peripherals. Key features include:

- Ultra-Low Power Sensing/Computing
- High Performance Core
- Large Internal Low Power Memory
- Rich Peripherals (for Sensors, and Connectivity)
- AP Resource Sharing (ex: Memory, Modem system)

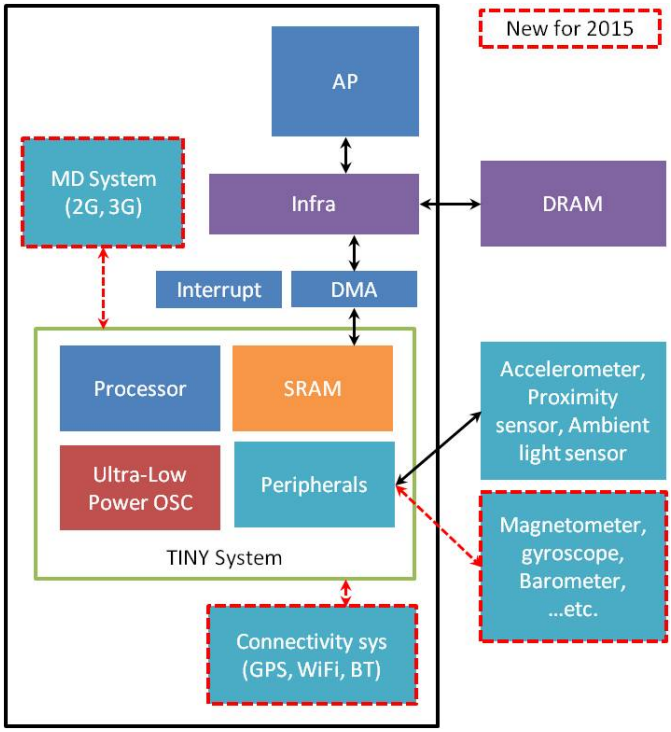


Figure 3. 2015 TINY Sensor Hub System Hardware Architecture

Ultra-Low Power Sensing/Computing

Three technologies work to achieve the ultra-low power sensing feature. First, the TINY System has independent power domains. This means that the TINY System power switch is separated from other components. The TINY System can operate its own power domain and work independently. Second, TINY System supports some power management methods, such as clock gated, power gated, sleep in the low voltage level, and DVFS (Dynamic Voltage Frequency Scaling). Last, ultra-low power OSC (referred to as ULPOSC) has very low active power and can rapidly be completely set up.

High Performance Core

The TINY System processor supports both of high performance and high power efficiency. The powerful ARM Cortex-M4F (CM4F) processor is used in the TINY System whose maximum frequency is 226MHz. CM4F can offer DSP acceleration and handle floating point by hardware. It consumes very low dynamic power due to the SoC design and the advanced manufacturing process.

Large Internal Low Power Memory

The memory cost associated with memory capacity and memory power consumption is an important concern in the sensor hub design. The TINY System provides a large SRAM, 512KB, which can be used to execute more applications or algorithms and let context-computing be more efficient.

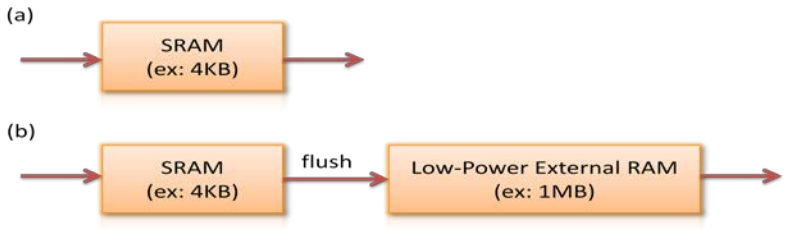


Figure 4. Fusion FIFO Mechanism

In addition to local SRAM, the TINY System proposes a *fusion FIFO* mechanism to store more sensor data or compute more features with minimal additional power consumption. Typically, the sensor data will

be only kept in SRAM as shown in Figure 4(a). If SRAM has no free space for storing new data, the AP needs to be awakened to handle the to-be-processed sensor data. When the SRAM size is small, the AP will wake up frequently and more power is generated. MediaTek proposes the fusion FIFO mechanism, a virtual memory concept, which is a large memory space, and consists of SRAM in the sensor hub chip and the low-power external RAM in the AP. The TINY System fusion FIFO mechanism makes good use of memory hierarchy to provide larger memory capacity and good access performance for always-on context applications with a little additional power overhead. The fusion FIFO mechanism can be used to completely support sensor batching function.

Rich Peripherals for Sensors and Connectivity

As shown in Figure 3 above, the 2015 TINY System adds more peripherals than MediaTek's 2014 product. The TINY System contains low-power peripherals such as I2C and UART, which can connect various sensors (e.g., accelerometer, proximity sensor, ambient light sensor, magnetometer, gyroscope, barometer, and so on), connectivity systems (e.g., GPS, Wi-Fi, BT), and Modem system (e.g., 2G, 3G). Currently, the up-to-date sensors officially announced by Android, including Android KitKat and Android Lollipop, are supported in the 2015 TINY System. When the connectivity system, modem system, and TINY system are manufactured in the same SoC, the connectivity system and MD system data can be directly accessed by the TINY System, thereby saving more power.

AP Resource Sharing (Examples: Memory, Modem System)

The TINY System can direct access some application processor resources, such as memory (e.g., DRAM) and modem system, without waking up the application processor. When compared with the external sensor hub solution which needs to wake up application processor to access AP resources, the TINY System can save power. The TINY System has very good scalability to access AP resources in the low-power state.

Based on the hardware architecture, the TINY System can support always-on context and has powerful processor and enough memory resources to process many sensor data. In addition, the TINY System provides a platform, which has enormous software algorithms to help to detect some user activity recognitions and other activities (e.g., gesture wake-up, voice wake-up and geo-fencing). The software

algorithms are tightly integrated within the hardware design to optimize the TINY System functions. The chart below shows power consumption for Android L motion detection—activity recognition + pedometer + significant motion detection.

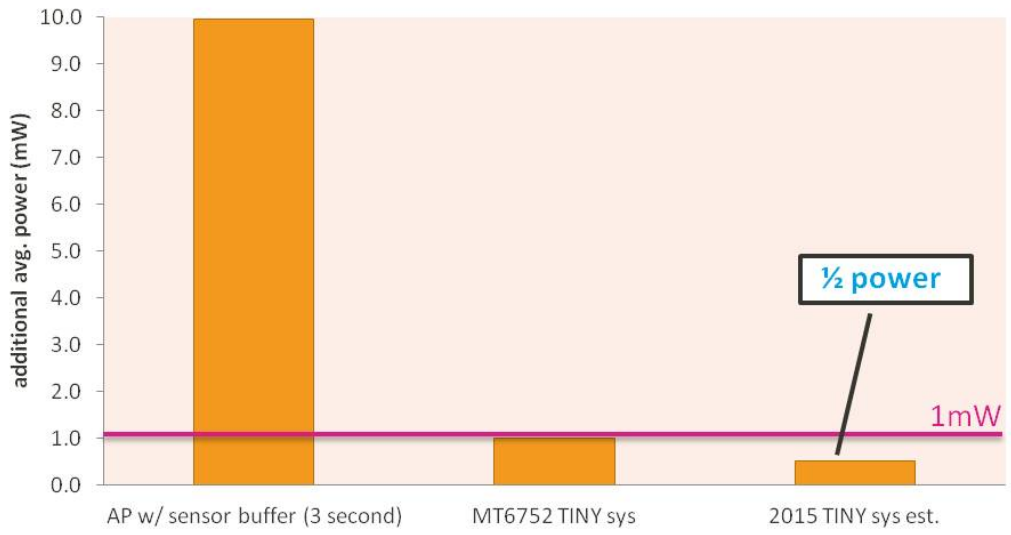


Figure 5. Power Consumption for Android L Motion Detection

In a nutshell, MediaTek's TINY System can provide the best solutions for always-on context by considering both hardware and software optimizations. A simple experimental result is illustrated in Figure 5 to show the power efficiency of the 2015 TINY System. Figure 5 shows the additional power consumption for the motion detection supported by Android L. The *AP w/ sensor buffer (3 second)* represents a simple design, in which the sensor has a hardware FIFO to store sensor data, and then the sensor data are processed or computed by AP. The *AP w/ sensor buffer (3 second)* has the highest additional power consumption. *The 2014 TINY System* consumes about 1mW. The 2015 TINY System achieves better power efficiency at a half of power consumption.

Conclusion

MediaTek's sensor hub solution, powered by the TINY Stem low power architecture, supports always-on context to efficiently perform motion/gesture detection, activity recognition, and context-aware

computing. The cost-effective TINY System takes advantages of the SoC and advanced semiconductor manufacturing processes to provide high performance processor, large SRAM and more peripherals to satisfy rich context-aware applications with ultra-low power consumption. The TINY System is embedded in the application processor chip, and no additional PCB components are required, resulting in very low additional BOM cost. The Fusion FIFO mechanism is adopted to compute complex context data or to store more sensor data. Moreover, the TINY System can provide the best support for the sensor processing of Android L/M, such as the features of sensor batching, and our proprietary sensor features, including significant motion detection and activity recognition.