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Wearable Sports Technology Market Landscape and SoC Trends

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A review of the benefits, applications, and System-on-Chip (SoC) technical trends in the area of wearable sports and fitness technology. Wearable solutions such as smart clothing and equipment embedded sensors are presented. Application examples in the game of golf and other sports are explored. Technical topics include low-power secure computing and efficient DC-DC power management solutions. Aspects of application software and algorithm intellectual property in relation to SoC innovation are discussed.

I. Introduction

Participation in sports activities and regular exercise are vital to a healthy lifestyle for people of all ages and backgrounds. In fact several prominent initiatives have been launched with sports involvement at their foundation. Noteworthy is the Millennium Development Goals [1] championed by the United Nations Secretary-General Ban Ki-moon, and the "Let's Move!" [2] campaign launched by the United States of America First Lady Michelle Obama. The objective is to promote daily physical activity, making sports an integral part of each program. It is widely recognized that sports activities are a powerful tool to help improve quality of life. Sports participation delivers many health, social, and mental benefits. For example, physical fitness improves resistance to some diseases; team sports help develop leadership and teamwork skills; and regular exercise improves self-esteem and self-confidence leading to better mental health.

From a business perspective, the sports industry is a valuable part of the global economy. It's reported that in 2014 the United States (U.S.) sports industry employed more than 1.5 million people, about 1% of total US employment [3]. Estimates put total worldwide sports industry revenue at $700 billion in 2014, which was approximately 1% of global GDP [4]. Over the next 5-10 years, wearable sports and fitness devices will be an important contributor to sports industry revenue. In 2020, this equipment segment is forecast to generate $9.4 billion in worldwide revenue at 103% compounded annual growth rate [5].

Wearable devices offer many benefits to professional athletes, amateur athletes, fitness consumers and wellness programs. Some of these benefits include player safety assessment tools, workout injury prevention, and metrics of physical conditioning and performance. An example is the game of golf where wristband wearable GPS sport watches are commonly used during practice sessions to improve swing mechanics [6].

Further, wearable devices encourage regular exercise and promote fitness. Owners of wearables report their devices help prompt regular fitness workouts. Market data show a "mobile generation" of users between the ages of 18 and 54 years account for almost 77% of wearable fitness device ownership [7]. This demographic embraces wearable sports technology and make it an integral part of their daily routine.

Beyond sports and fitness benefits, there is potential to elevate the sports fan viewing experience. Using wireless sensors embedded in player equipment or uniforms, sports viewers will have real-time access to movement tracking data and performance statistics like acceleration and top speed. With analytics and enhanced graphics, this technology can dramatically change live television broadcast of major sporting events.

Considering the social, health, and economic benefits derived from exercise and sports activities, the ISOCC Technology for Sports session is a timely topic. Essential to the successful development of wearable sports devices, System-on-Chip (SoC) innovation is required in the areas of microprocessor computing, power management, sensor fusion, and device connectivity. This paper explores application possibilities in the sports and fitness wearable device space. Select SoC technology trends are presented in the areas of low-power secure computing and efficient DC-DC power conversion. The SoC integration ecosystem related to mobile application software and algorithm intellectual property (IP) is discussed.

II. Applications Landscape

The applications landscape of the wearable sports and fitness market segment includes wristband devices, sensor embedded equipment and smart clothing using woven technology or printed electronic materials. **Figure 1** illustrates some of the different end applications. **Figure 2** shows the results of a recent survey on consumer interest levels in wearable sensor devices [8]. Wristband wearables have the highest consumer interest level. Examples of wristband devices are fitness bands and GPS golf watches. In the U.S., sensor embedded equipment is being evaluated by the National Football League where Radio Frequency Identification (RFID) sensors are embedded in the shoulder pad equipment of players.

Figure 1. Examples of end applications for wearable sports technology include the sports watch, embedded sports equipment, and garments.

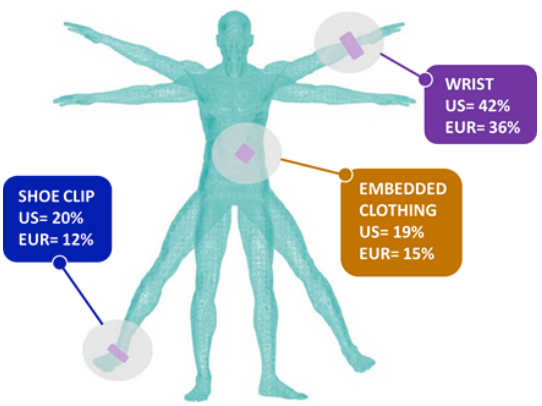

Figure 2. Consumer interest level is highest for wristband sensor devices.

In real time, the system gathers player movement tracking data and performance statistics. This also serves as a practical example of Internet of Things (IoT) edge analytics where computing is moved closer to the source of data as opposed to a centralized cloud node.

Smart clothing, using woven technology from Sarvint Technologies [9], demonstrates possibilities in textile engineering. Sarvint uses special fibers that are woven into garments which act as a conduit to transmit and receive the body's vital signs to a central processing unit. Another technology for wearables, printed electronic ink, enables a circuit to be printed into a garment whereby body sensors can be connected to a central processing unit. These exciting application developments for sensing physiological parameters, tracking body movement, and delivering edge analytics are enabled by technology advancements in SoC solutions.

III. SOC TECHNOLOGY TRENDS

A. System Partition Options

Practically all wearable devices must meet design criteria of miniature size, operation at ultra-low power, sensing of physiological or local environmental parameters, and capable of communicating with the network edge. Core technologies required for design of wearable sports and fitness devices are the microcontroller (MCU) central processing unit, power management integrated circuit (PMIC), sensor elements, and sensor signal conditioning analog front end (AFE). When designing a wearable device, there are three system partition options available to engineers; MCU with integrated high-performance AFE (**Figure 3**); MCU with integrated basic AFE (**Figure 4**); MCU with a distributed AFE (**Figure 5**). Typically Option-1 and Option-3 are needed when working with electrode-based sensors that require analog signal conditioning. Option-2 is useful for digital interface sensors that integrate on-chip signal conversion. Depending on product system requirements, designers need to select the best option based upon form factor and size, power source and operating life, desired precision, and accuracy.

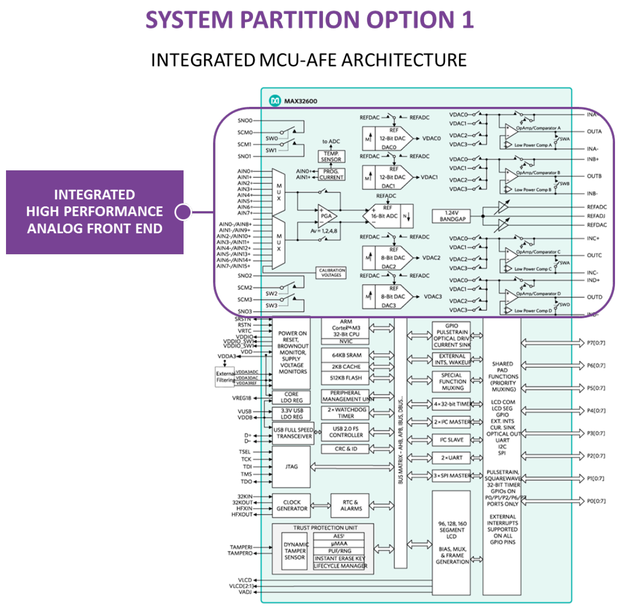

Figure 3. MCU with integrated high performance AFE is one option available for complex or precision sensor signal conditioning.

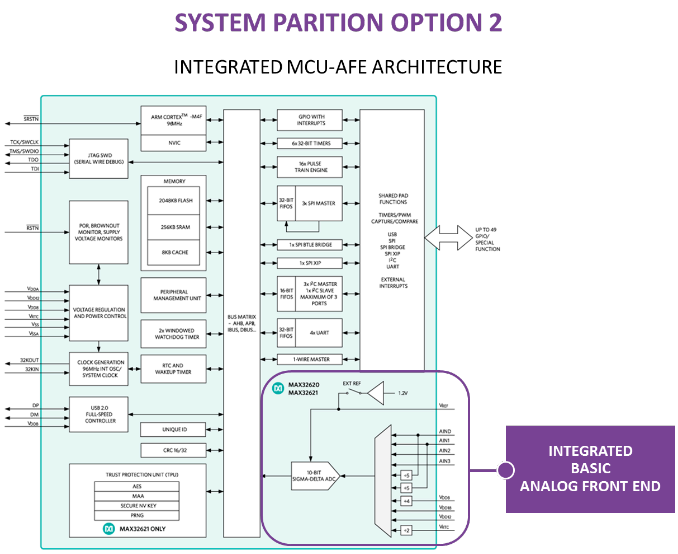

Figure 4. MCU with integrated basic feature-set AFE is a suitable system partition for wearable devices employing digital interface sensors.

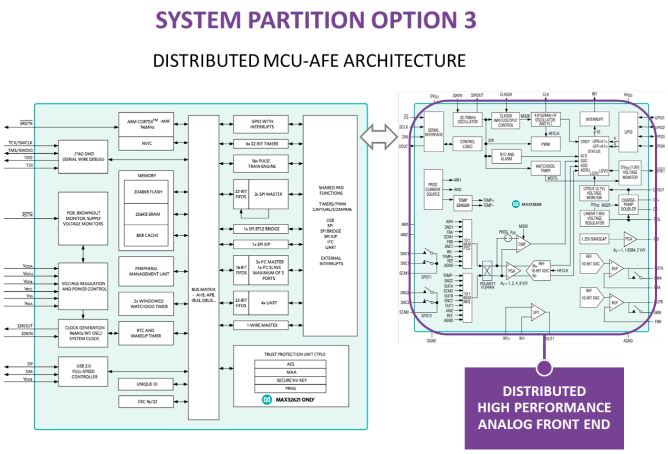

Figure 5. A distributed circuit partition uses a stand-alone high performance AFE.

B. Compute SoC Trends

Adoption of strong MCU security measures, more memory capacity, and special attention to power-optimized memory access methods are three technology trends anticipated for next generation compute SoC solutions. Figure 6 illustrates the compute SoC integration trends.

Wearable devices are vulnerable to security threats. Strong security measures are critical to protect against malicious attacks that can corrupt or steal data. Security is needed to protect intellectual property such as proprietary algorithms that could reside on a wearable device. Secure authentication prevents device cloning and offers counterfeit protection for peripherals. To counter these threats, SoC designers should consider building multiple layers of cryptography and physical security into the MCU architecture. Figure 7 captures the critical security features found in a MCU Trust Protection Unit. An example is the MAX32621 microcontroller with integrated Trust Protection Unit [10]. As wearable sports and fitness devices converge with the IoT, security must be at the forefront of the MCU design and selection process.

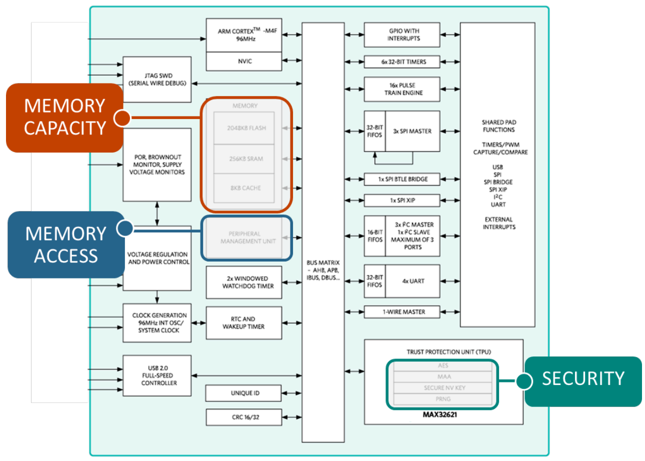

Figure 6. To address edge analytics, IoT security and low power, Compute SoC trends include MCU integration with more memory capacity, power efficient memory access, and strong security measures.

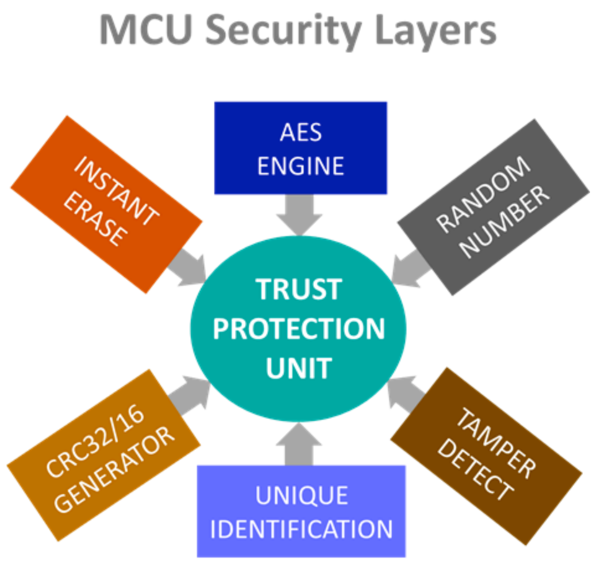

Figure 7. A strong MCU Trust Protection Unit requires multiple layers of cryptography and physical security.

Wearable devices will need more memory capacity. This is driven by the confluence of an increasing number of sensor elements, the need for mobile software applications, and the rise of edge analytics. In 2020, the average wearable device will integrate 4.1 sensor elements, almost a 3x increase from 2013 [11]. More sensors create more data volume which increases communication network traffic between wearable devices and edge access points. To reduce communication link congestion, the data throughput over local area networks must be minimized. By moving analytics processing closer to the device, there will be less network data traffic and by nature less congestion. This is one of the primary benefits from edge analytics. Consequently, extra signal processing must be done within the wearable device. Meaning proprietary algorithms used to process sensor data, as well as mobile application software, will reside in the wearable device, thus demanding more memory capacity. From a system level perspective, more memory results in higher power consumption.

To better manage power consumption, direct memory access can be power-optimized with a dedicated Peripheral Management Unit (PMU). The PMU is a programmable state machine that executes opcodes and operands resident in the main MCU memory space. This methodology off-loads the main processor core from servicing memory and peripherals with the effect of lowering total operating power.

C. Power SoC Trends

Diligent power and battery management design techniques are needed to achieve ultra-low operating power and long operating life from the smaller size and lower capacity batteries used in wearable devices. A complete power SoC solution, i.e. PMIC, should integrate power management and battery management functions that are optimized for wearable applications.

The operating profile of wearable devices differs significantly from mobile devices like smartphones. **Figure 8** shows the low duty cycle operating time typical of a wearable device [12]. Much of the time a device is in ultra-low power standby-mode and at different times wakens to active-mode where power consumption is much higher. Note that 25% of battery capacity is consumed in standby-mode. Because of this operating profile, the PMIC quiescent current and efficiency performance across a wide load range are critical. Moreover, the battery fuel gauge algorithm must be accurate and stable to achieve maximum operating time before charge cycles.

A PMIC solution with embedded fuel gauge algorithm, complete battery charging system, and multiple high efficiency DC-DC regulators will allow wearable devices to realize miniaturization, long operating time, high reliability and low system cost. An example PMIC is the MAX14676 (**Figure 9**), a miniature charge management solution for wearable electronic devices like fitness monitors and GPS sports watches [13].

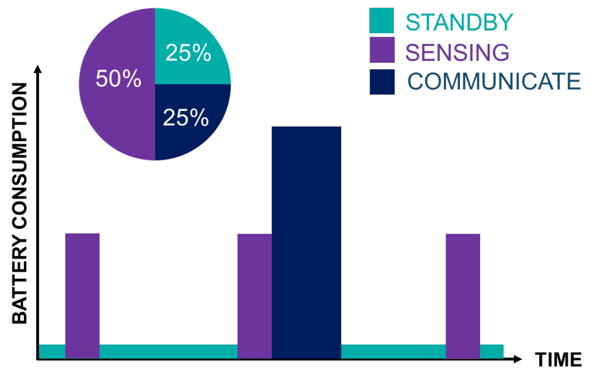

Figure 8. Simple illustration of battery consumption and how much time a wearable device is expected to operate in three different modes.

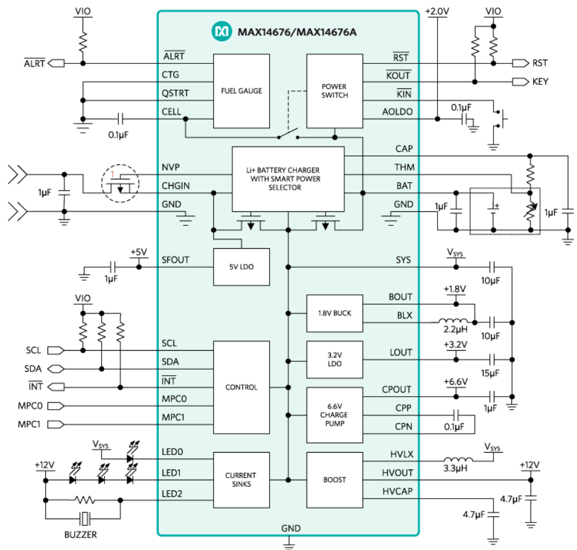

Figure 9. An application specific PMIC with embedded battery fuel gauge algorithm and high efficiency DC-DC converters helps achieve miniature size and long operating life.

IV. Ecosystem – Apps and Algorithms

Advancements in the area of sports technology require strategic partnerships and cooperation within the business ecosystem. **Figure 10** identifies the ecosystem contributors. Among them are developers of mobile application software and sensor IP.

Mobile application software and sensor signal processing algorithms are fundamental parts of the wearable ecosystem. Each serves a unique role in bringing together the analog domain, digital domain, and human interface to deliver a meaningful user experience. After all, the purpose of a wearable sports or fitness device is to accurately acquire physiological data, reliably process and analyze the data, and ultimately presents the results in a way that is helpful to users in making better life decisions.

Licensing agreements with partner developers can add considerable value to a wearable device product development effort. By providing technology expertise that enhances system performance or offering application software that improves the mobile user experience, partner developers play an important role in bringing successful products to market. Some areas of expertise include sensor accuracy and data analysis technology. Examples of companies specializing in these areas include Valencell, Inc., a developer of high performance biometric sensor technology, and FirstBeat Technologies Ltd., a provider of physiological analytics for sports and fitness.

Valencell employs a proprietary technology based on photoplethysmography using reflectance-mode optical sensors to measure blood oxygen saturation [14]. The measurements provide activity metrics such as continuous heart rate and calories burned. FirstBeat has developed an analytics technology that models a user's physiology based on heart beat measurement [15]. The modeled results provide a user with information about work-out effectiveness, work-out recovery advisement, and cardiovascular fitness based on maximum oxygen consumption (VO_{2MAX}). The technologies from both companies can be licensed to product developers.

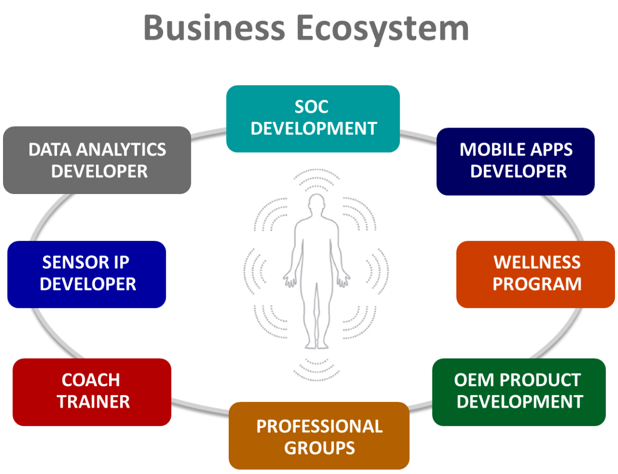

Figure 10. The business ecosystem relies on collaboration among many partners.

Technology innovation for next generation sports and fitness wearable devices requires cooperation among all ecosystem participants. Professional societies and conferences like the IEEE and ISOCC are excellent ways to share ideas, express thought leadership concepts, develop business relationships, and identify potential strategic partnerships.

V. Conclusion

Sports participation and regular exercise promote health, social, and mental wellness. Wearable technologies for sports and fitness activities can deliver many benefits to professional athletes, amateur athletes, fitness consumers, and wellness programs. Moreover, economic benefits can be realized from new business models and employment opportunities. SoC research and development is a catalyst for advancing the next generation wearable products. Innovations in the areas of low power secure computing and efficient power management solutions are inspiring new application possibilities for smart clothing and embedded equipment. Moving innovation forward will require business ecosystem collaboration and strategic partnerships. In the coming years, we can expect to see widespread adoption of wearable sports technology as a tool to promote healthy lifestyle choices.

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