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White Paper

Overcoming the Size and Power Trade off in Wearable Designs

Introduction

There is a real buzz around wearable technology with headline-grabbing news announcing the exciting devices that are coming to market. The term 'wearables' describes all aspects of technology that can be worn on the body from wristbands, watches, glasses, clothing, footwear, jewelery and beyond. The bounds of wearables are limitless and are expected to be the next big growth area in smart portable devices.
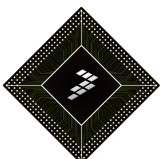
So why are wearables so interesting and why are they gaining such attention? A wearable device worn on the body (not just humans, but also animals) has the profound ability to integrate into our daily lives in a way unlike any other device. The smartphone comes close and most of us wouldn't dream of leaving the house without our phone; but with a wearable, it becomes even more personal and more connected to our daily lifestyle by capturing contextual data in our environment. Rather than being carried in a pocket or a bag, the wearable actually lives on us, experiencing what we experience and unobtrusively becoming a companion to our digital lifestyle.

The device itself is only half the story. The real power is in connecting the device to the cloud, and in turn, to apps and services that travel with us. Early examples of wearable devices fall broadly into three categories: fitness activity trackers, watches (smartphone second screen) and glasses

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(smartphone second screen and augmented reality). All of these devices have the ability to gather data via sensors to make sense of your daily activity and connect to the cloud so analytics can be performed on the data. Behavioral and health analytics is the key to changing or improving lifestyles and increasing the "stickiness" of the wearable device. In other words, making the wearable device an automatic companion. Many of today's fitness trackers are worn for a few months and then forgotten and left in a drawer. The challenge and goal of wearable device manufacturers is to create something that becomes an automatic companion for the long haul.

This white paper outlines how ARM and Freescale are working together to deliver market-leading semiconductor solutions for wearable devices. Paramount to this is the ability to deliver ultra-power and space-efficient solutions that translate into small form factor devices that last longer on a single charge.

This white paper will also provide a detailed overview of how the wearables market is evolving, examine some examples in the market today and discuss the technologies necessary to deliver low power and special requirements. Finally, we'll look at the role of the innovator and the tools and platforms to help fuel innovation in the wearable technology space.

Wearable Technology Market Overview

Wearables are often viewed as the most exciting and promising new technology. Although this is true, we are also reminded of the fact that wearables already exist today with a number of exciting products on the market and new devices arriving all of the time. We see wearable technology going through a rapid innovation phase where new and previously unheard of companies often raise money through crowd sourcing ventures such as Kickstarter, and within 12 to 18 months, can be shipping products. Existing well-known OEMs are entering the wearable market at a rapid pace with their own wearable solutions.

When we look at the market, we see three categories of devices dominating the wearable landscape:

- Fitness/Activity Trackers – devices worn on the wrist or clipped to the body that track activities such as running, walking and sleep patterns
- Watches – used as a second screen to display smartphone notifications
- Glasses and Cameras – glasses used as an augmented reality smartphone providing a second screen and wearable cameras

Beyond these three main product categories, we also see some fascinating new areas opening up for wearable devices such as:

- Smart clothing – clothing based on smart textiles or LED lighting, expanding to smart shoes and jewelery

- Healthcare – remote patient monitoring, lifestyle coaching, ECG (heart rate monitoring), continuous blood glucose monitoring and wearable wireless patches for diagnosing conditions like cardiac arrhythmias

- Authentication – payments and banking, car ignition, home automation controlled by a wearable device

- Gaming Headsets and Earbuds - headphones that deliver rich sound and an integrated microphone

So, what does all this mean for the future of wearables? Single-function devices, such as fitness bands, will continue to be popular. Over time, we expect to see an evolution similar to that seen in the smartphone space where the wearable device will gradually pull more and more functionality into a single device and create the "stickiness" needed for wearable devices to become the norm. How will that look? It is hard to predict. We expect to see a fusion of the categories listed above—for instance, a watch that acts as a second screen to your smartphone, tracks your daily activity, monitors your health, connects you to your family, friend or care givers and also has secure integrated banking functionality so that you can use it to authenticate payments. Wouldn't that be a great all-in-one wearable device?

Wearables in Action

With the market's broadest and best-enabled portfolio of solutions, Freescale's ARM-based MCUs and processors are ideal for all types of wearable product designs. The scalable MCU and processor families range from small ultra-low-power Kinetis MCUs, such as the KL03 chip-scale package (CSP)—the world's smallest ARM Powered® MCU, to i.MX applications processors with hardware graphics acceleration to enable designs with higher level operating systems such as Linux® and Android™ as well as richer user interfaces.

Many wearable devices available on the market today are powered by Freescale MCUs and processors, built on ARM architecture. The ARM architecture provides a processing engine with low power and scalability in performance that makes it an ideal solution for wearable devices. The broad spectrum of wearable applications ranges from fitness bands and smart watches to cameras you can mount on your head and even activity trackers for your dog. Here's a quick look at some of them:

Activity/Fitness Trackers

Low power, performance and cloud connectivity make the **Withings Pulse activity tracker** appealing to today's active health-conscious consumer with a small, easy-to-wear form factor. This activity tracker can be worn multiple ways as a clip-on device or on a wristband. The scalability of Freescale's Kinetis family of MCUs make it more efficient (faster time to market) and cost-effective for Withings to design new devices.

The **Thalmic Labs MYO** is an armband that works by using the electrical activity in your muscles to wirelessly control your computer, phone and other favorite digital technologies with a wave of your hand. The armband connects to your computer or other smart device via Bluetooth® so you can swipe through web pages, turn the music volume up, change slides during a presentation and even play games. The MYO is powered by Freescale's Kinetis K20 MCUs.

And then there's the **Whistle Activity Monitor**. It's not an armband or a wristband, but rather a neckband—for dogs, that is. Powered by Freescale's Kinetis K60 MCU, the Whistle Activity Monitor is a waterproof, on-collar device that measures your dog's activities including walks, play and rest, giving you a new perspective on your best friend's behavior and health trends. Check in from your smartphone, share memorable moments with friends and family, and send reports to your veterinarian on any changes in behavior or health.

Watches

Another popular category is watches. **Garmin's Forerunner® 10 and Forerunner 15 GPS watches** track distance, pace and calories at the press of a button, enabling you to enjoy the benefits of a sophisticated GPS watch without the bulk. The Forerunner 10 is powered by a Cortex-M4-based Kinetis K20 MCU and the Forerunner 15 uses a Kinetis KL26 with a Cortex-M0+ core. Featuring a high-resolution color display, access to training plans, and the ability to measure your essential running stats, the **Forerunner® 220 and Forerunner® 620** are like having a personal coach in your pocket. The Forerunner 220 and the Forerunner 620 are powered by Freescale's Kinetis K22 MCUs.

Freescale's i.MX233 applications processor powers the Android-based **i'm Watch** which connects to your smartphone so that you can use it for inbound calls and text messages. Facebook, Twitter and weather forecasts look their best on its high-resolution screen and nice user interface.

Glasses and Cameras

OrCam has created an eyeglass-mounted device for the visually impaired that allows them access to activities that most people take for granted such as riding the bus, shopping for groceries or reading the newspaper. Powered by Freescale's high performance and energy efficient i.MX 6Quad processor, the OrCam solution employs sophisticated visual computing algorithms to interpret visual inputs and communicate their meaning in real time to the person wearing the technology. This is a wearable that is truly aiding the disabled.

Using the Kinetis K20 MCU, the **GoPro HERO3+ camera** is wearable, gear mountable and waterproof. It's capable of capturing professional-quality video at high resolutions. With increased image sharpness, improved audio, longer battery life and speedier Wi-Fi® sharing, HERO3+ makes capturing and sharing your life easier than ever.

Healthcare

Numera Libris gives today's active seniors and their families freedom, security and the ability to manage their health at home or away. Powered by the Kinetis K70 MCU, the Numera Libris personal health gateway integrates telehealth advantages and safety features in one small, easy-to-wear mobile device.

Designing Wearables

The key design challenges faced by wearable device manufacturers are form factor, power consumption and the user experience. When we look at the wearable technology space, we move to a whole new set of design rules compared to handsets. Typical wearable devices today broadly fall into two areas:

• Designs that are based on low-power, high-performance MCU functionality

• Designs that are based on handset applications processing functionality, similar to the processors you find in smartphones

Below is a table that shows how the application requirements drive the type of MCU or applications processor and the ARM Cortex® core it is built upon.

Wearable Application Requirements

Application Requirements	Recommended MCU/ Applications Processor	ARM Cortex Core
Low power for single-function devices such as: • Low end activity trackers • Headphones • Heart rate monitors	Kinetis K and L series MCUs	ARM Cortex-M series
Higher performance with greater functionality, full operating system and graphical user interface support such as: • Smart watches • Glasses	i.MX applications processors	ARM Cortex-A series

The performance and power of the two categories of devices are starkly different, with the handset application processor-based designs demanding higher operating points delivering reduced battery life compared to microcontroller designs.

Form Factor

If we look at a typical wearable and consider the design constraints, we immediately see the first challenge is form factor. A wearable device needs to be small and unobtrusive. This places harsh constraints on the available PCB area, reduced battery capacity and very limited thermal budgets. A typical high-end handset has a battery capacity of around 3000 mAh as opposed to only around 300 mAh for a watch. With only around 1/10 of the battery capacity of a handset, very careful consideration of the energy requirements

is necessary to minimize recharge cycles. Today's consumers are used to charging their smartphones daily, but with wearable devices consumers expect that the recharge cycle should be no more than once a week—or ideally, only once a month. In reality, the reduced battery capacity and reduced recharge cycle means that we are looking at up to 1/50th of the available energy for a smartwatch versus a smartphone. The need for small form factors can be achieved through silicon integration and advanced packaging technologies. Freescale's Kinetis portfolio of Cortex-M family cores integrate memory, peripherals such as USB and touch sensing and analog components to reduce overall system size. Kinetis MCUs are offered in various packages, including wafer level chip scale packaging (WLCSP) to get maximum performance in the smallest possible footprint.

Power Consumption

Android-based wearable devices have hardware system requirements that prohibit the use of the microcontroller's limited capabilities. For these devices, designers need processors that support features such as memory visualization, graphics support and increased CPU bandwidth. Tailoring a Cortex-A based processor such as i.MX applications processors to the wearable device's low-power envelope is critical. The optimal power/performance trade-off is achieved through lower clock speeds versus traditional handset processors (e.g. 500 MHz vs 1 GHz) to optimize the core configuration of the device to the application (e.g. smaller cache memories and low leakage process nodes).

Looking at the use case of a smartwatch, we see that the device spends over 80% of its time in sleep mode and simply monitoring sensors that are capturing data in the environment and occasionally refreshing the display. With users glancing at the screen to get updates rather than interacting with the device in the way we do a smartphone, user interaction with a smartwatch tends to be less frequent.

User Experience

The usability of a wearable device is highly dependent on how someone interacts with the device and the interface sets the stage for the user experience. Design considerations that need to be investigated to provide this experience include: display or no display, type of connectivity, methods and frequency of charging and the overall style.
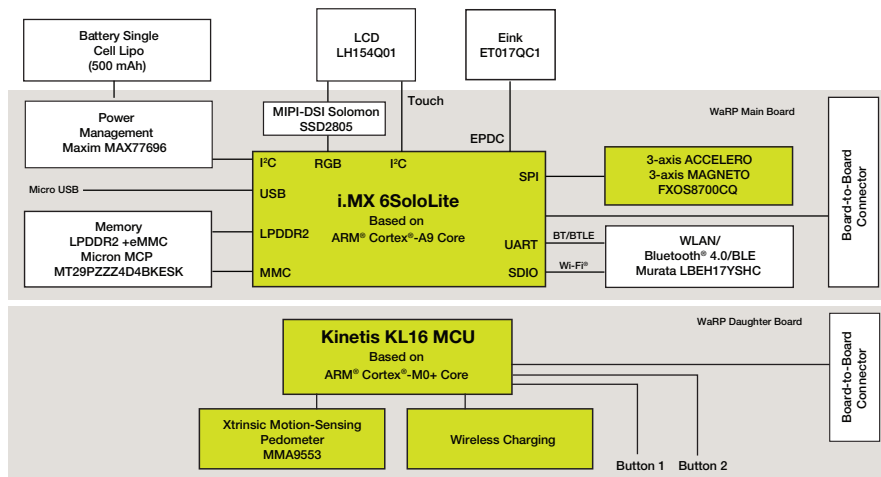
A critical aspect to implementing these design considerations is the software. What type of operating system should the device run? A full operating system like Android or Linux gives more capabilities with enhanced graphics, broader connectivity options and simpler expandability. However, these capabilities also have an impact on form factor, battery life and cost as they require an applications processor-level device to implement. Real-time operating systems can be implemented in a smaller footprint to take advantage of microcontrollers with embedded memory to achieve smaller size, longer battery life and lower cost. The trade-off is in the graphics capabilities, overall performance and future features support options. Many questions need to be asked and trade-offs analyzed by a wearable device developer before deciding on an architecture for the end product.

Enabling the Innovator

Enter the wearable reference platform, or **WaRP** for short. This reference platform facilitates wearable designs by taking a hybrid approach to help solve these form factor and power consumption design challenges. By speeding and easing development, developers can focus on creating differentiated features and get from prototype to product faster.

The platform consists of a main board and an example daughter board with the ability to add additional daughter boards for different usage models. The hybrid architecture combines an ultra-low-power Kinetis KL16 MCU, built on a Cortex-M core, with an i.MX 6SoloLite applications processor, built on a Cortex-A core. This way, the MCU can manage the sensor data while the applications processor can stand by in power savings mode, thus saving energy and extending battery life. The Kinetis MCU is also used as a wireless charging MCU. All components in the WaRPboard were selected based on low power, small form factor and cost.

Wearable Reference Platform (WaRP) with Standard Daughter Board

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WaRPboard is a collaboration between companies with technology and experience in the wearables market. As the enabling technology provider, Freescale provides the MCU, applications processor, sensors and wireless charging technology comprising the WaRPboard. Several other companies provide hardware and software development and manufacturing expertise. The implementation on WaRP is a standard Android SDK approach to allow software developers to run their applications simply and quickly. WaRPboard.org is a not-for-profit, community-based organization providing service and support for WaRP. The solution's hardware and software will be open sourced and community driven so no closed development tools or licensing fees are required when used in conjunction with open source resources.

Its compact design, optimized battery life and battery management, scalable architecture, productizable design and open source and community-based innovation make the WaRPboard a natural first step for wearable device designers.

Summary

The future of wearables holds huge potential. The ability to combine mobile technology with personal user centric experiences will ultimately unlock this exciting and fast-paced market. Whether you are using your wearable to monitor fitness, get context aware alerts and notifications or even monitor your health and wellness, the potential of wearable technology is without bounds.

As evidenced in this paper, the ability to combine ultra-low power design with always on, always connected functionality is a critical requirement. Extending device battery life, reducing the necessity to recharge, and minimizing the form factors of wearables to a point where they are small and unobtrusive are key design challenges facing the industry today.

ARM and Freescale are working to address these market needs, and together are fuelling the wearable revolution. ARM Cortex 32-bit cores are uniquely positioned to address the 'one size doesn't fit all' needs of the wearables space and bring an unrivalled breadth of developer ecosystem, a critical component of driving innovation. Freescale's Kinetis MCUs and i.MX applications processors are perfectly positioned to address the wearables market and there are already a number of exciting designs out there today.

You can be sure that there are many exciting innovations still to come in wearable design and ARM and Freescale are working tirelessly to enable those future generations of devices.

Contributors

This white paper was developed in collaboration with wearables experts from Freescale and ARM.

ARM

For more information about how Freescale and ARM are impacting wearables, visit freescale.com/wearables and arm.com.

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