SAMSUNG
BIO-PROCESSOR
FOR WEARABLES
SAMSUNG BIO-PROCESSOR FOR WEARABLES

SAMSUNG BIO-PROCESSOR WEARABLES FOR SELF-HEALTH ASSESSMENT AND MONITORING

Summary for Decision Makers

Personal health and fitness have become more important than ever before, with people adopting more sustainable lifestyles, better nutrition habits, and increased physical activity. Wearable devices that support self-health assessment and monitoring have been proven to measurably improve user wellness. However, most wearables are only able to measure motion-related data.

To enable a new generation of health monitoring wearables, Samsung offers the Bio-Processor, a compact, affordable, all-in-one solution. Analog sensors monitor user biodata like heart rate, body fat, and stress levels. An energy-efficient digital signal processor (DSP) significantly reduces average power consumption, for long battery life. The microcontroller (MCU) is powerful enough to handle both health/fitness algorithms and host processing for lightweight devices like fitness bands or smart clothing. Sensitive sensor data is secured by hardware-based encryption.

With the Bio-Processor, Samsung helps empower today’s consumers to live healthier, more active and smarter lives.

The Rise Of Self-Driven Health Care

Certainly everyone wants to be healthy; the question these days is how best to support this goal for all users. Today’s consumers are increasingly health conscious and want to lead long and active lives as free as possible from critical illnesses. They are better informed about their fitness and gather information from a variety of media sources such as WebMD, MedHelp, Health24 and NetDoctor. They also know that the absence of illness does not necessarily mean wellness. Illnesses can develop slowly, which makes monitoring for warning signs like elevated heart rate, high blood pressure, increased body fat and chronic stress particularly valuable. Diet, exercise, proper medication, stress management, and other practices have increasingly become a part of a modern lifestyle.
At the same time, consumers have to deal with soaring costs for health care. According to estimates, the per capita cost of health care in the U.S. is now more than $10,000.\textsuperscript{1} Since much of this growth is toward high-deductible programs, visits to the doctor or hospitals can lead to significant costs even for the insured. Younger individuals who are usually healthy can feel that high insurance premiums are a waste of their money.

All these factors have encouraged consumers to explore new ways to support self-driven health care, including fitness tracking, illness self-prediction and immediate treatment. They want to track their frequently changing lifestyles, habits, and emotions in real time, using technology to identify issues such as eating disorders, sleep apnea, and elevated stress levels. They also see the value in digital devices that help them set realistic goals for workouts and measure their progress over time. A record of accurate, up-to-date data can motivate users to climb that extra flight of stairs or help someone monitor their weight, stress or sleep patterns. Most important, effective wellness monitoring can provide critical warning signs to help prevent life-threatening disease.

**On the Road to Self-Monitoring Technology**

**Benefits Achieved by Remote Medical Monitoring**

\begin{itemize}
  \item 71.2\% of patients achieved better blood pressure control in a study published by HealthPartners Institute for Education and Research
  \item 19.5\% reduction in 30-day all-cause readmissions of Medicare beneficiaries, as seen by the Geisinger Health Plan
  \item New York City Health and Hospitals Corp. recorded a 21\% decrease in mortality rates; 16\% reduction in heart failures; 14\% drop in heart attacks and 12\% reduced risk for stroke in diabetic patients
\end{itemize}

Until recently, traditional health monitoring required multiple in-hospital or facility-based devices that relied on large, bulky devices that were costly to purchase, deploy, and maintain. Each device had to be specialized for monitoring specific functions and conditions such as cardiac activity, blood pressure and blood flow, pulse rates, carbon dioxide levels, and blood glucose levels.

Employers sponsored periodic health checkups, and health-insurance packages offered free checkups. But these involved time-consuming visits to diagnostic labs. In addition, most employers and health insurance provided only one check-up per year. Effective health care depends on regular engagement, but these checkups were too inconvenient and expensive to perform on a frequent basis. Data was not secure, and patients were sometimes uncomfortable because people outside of their family and primary physicians could see their personal test and monitoring results.

\textsuperscript{1} US healthcare spending has hit a new high — $10,345 per person, Business Insider, July 14, 2016
To address these issues, activity-tracking portable devices with sensors were introduced in the early 2000s. Using motion-based sensors such as accelerometers and pressure sensors, wristband-type wearables measured steps walked, stairs climbed, calories burned, sleep quality and hours of sleep. Heart rates were recorded through separate devices like chest straps.

However, key problems remained. Although these wearables enabled personal health monitoring by both physicians and consumers, they had rudimentary capabilities due to the simple sensors they used. They were also dependent on other devices for data measurements, analysis, and display, such as bulky chest straps. Equally important, the results were not precise by today’s standards, and without continuous capture were actually misleading at times since heart rates and stress levels change so much throughout the day. Thus, consumers were often confused about their health state because they had only a few metrics that provided them with an incomplete picture. Wearables capable of delivering a more complete picture, in a comfortable form factor, simply did not exist.

According to recent Gartner research, over 180 million wearables with health/fitness-related functions will ship in 2017. All of these devices are involved in enabling physical activity outdoors or indoors, and all are intriguing vehicles for tracking user health.
Samsung Bio-Processor: an All-In-One, Quantified Health Care Solution

Bio-Processor

Samsung Bio-Processor merges five different sensors in a single chip, empowering manufacturers to provide an in-depth monitoring of the human body.

Providing a variety of fitness data

- **Body Fat**
  - **Body Fat Percentage**
  - BIA sensors can measure body fat, adjusting for normal or athletic users.

- **PPG**
  - **Photoplethysmogram**
  - PPG sensors can monitor heart rate and respiration.

- **ECG**
  - **Electrocardiogram**
  - Electrocardiogram readings measure heart rate and heart rhythm, testing general heart health.

- **Skin Temp.**
  - **Skin Temperature**
  - Temperature sensors measure skin temperature to obtain overall body temperature.

- **EDA (GSR)**
  - **Galvanic Skin Response**
  - (also called EDA) readings measure stress levels and emotional state.

Samsung’s Bio-Processor is designed to overcome the limitations of earlier health monitoring devices, giving consumers the technology they need to take a greater role in managing their health.

The Bio-Processor is a low-power, system-on-chip (SoC) solution that processes five critical types of biodata – electrocardiogram (ECG), photoplethysmogram (PPG), bio-electrical impedance analysis (BIA), galvanic skin response (GSR), and skin temperature (SKT). These are integrated with an MCU, DSP, memory, power management, security blocks, and low-power analog components in a compact 5.7mm x 4.9mm package. Samsung also provides several algorithms to calculate user metrics from heart rate and variability to body fat percentage, plus a software development kit (SDK) for device makers to configure their own algorithms.

The Bio-Processor has been carefully architected to meet the needs of today’s consumers, who are looking for increasingly detailed and accurate fitness data. With the Bio-Processor, Samsung provides a complete platform to enable a new generation of discreet wearables that bridges consumer- and medical-grade technology. As healthcare grows more expensive, such devices are key to complementing cost-effective plans with accurate, sophisticated user fitness data.

Designed for modern lifestyles, the Bio-Processor supports a wide range of accessories that fit seamlessly into the user’s daily activities. Watches, headphones, clothes and other products can incorporate the Bio-Processor to deliver real-time health results that are actionable for the user. The Bio-Processor’s MCU and on-chip memory help in storing and retrieving data without the need for an online connection.
Sensitive user data is safeguarded by Advanced Encryption Standard (AES) support, to hide data from hostile actors. Users can feel secure in sharing data from the Bio-Processor with approved parties such as family, friends, and doctors.

### Technical Highlights

#### Bio-Processor

<table>
<thead>
<tr>
<th>Features</th>
<th>Bio-Processor (S3FB5A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Acquisition and</td>
<td></td>
</tr>
<tr>
<td>Processing</td>
<td></td>
</tr>
<tr>
<td>AFE</td>
<td>ECG, PPG, BIA, GSR</td>
</tr>
<tr>
<td></td>
<td>5x 12-bit SAR ADC</td>
</tr>
<tr>
<td></td>
<td>1x 24-bit ΣΔ ADC</td>
</tr>
<tr>
<td>MCU</td>
<td>Cortex-M4F (87MHz)</td>
</tr>
<tr>
<td></td>
<td>FLASH (512KB), SRAM (256KB)</td>
</tr>
<tr>
<td>DSP</td>
<td>Ultra-Low Power-SRP (87MHz)</td>
</tr>
<tr>
<td></td>
<td>CMEM (10KB), IMEM, (128KB), DMEM (128KB)</td>
</tr>
<tr>
<td>Security IP</td>
<td>AES (Advanced Encryption Standard)</td>
</tr>
<tr>
<td></td>
<td>DTRNG (True Random Number Generator)</td>
</tr>
<tr>
<td>Power Management</td>
<td>DCDC, 4x LDO, POR, Keep Alive LDO</td>
</tr>
<tr>
<td>Interfaces</td>
<td>3x UART, 5x SPI, 5x 12C, 2x GPIO</td>
</tr>
<tr>
<td>Power Supply</td>
<td>Digital/AFE: 1.1V</td>
</tr>
<tr>
<td></td>
<td>LED driver: 2.7 ~ 3.3V, 5V</td>
</tr>
<tr>
<td></td>
<td>IO Power: 1.8V</td>
</tr>
<tr>
<td>Package</td>
<td>FO-WFP, 5.7mm x 4.9mm</td>
</tr>
</tbody>
</table>

#### Versatile Configurations

- **Health Sensors**: ECG, PPG, BIA
- **Digital Sensors**: Accel, Gyro, Temp

- **Co-Processor**
  - Display
  - BLE
  - SPI
  - PMIC
  - EEPROM

- **Stand-Alone**
  - BLE
  - UART
  - SPI
  - EEPROM
  - GPIO
  - LED
Low-power design for longer battery life:
Different power states let the MCU efficiently support essential tasks while delegating the rest to the DSP. Bio-Processor also enables an ambient user experience through continuous low-power data sensing, with the MCU and DSP in sleep mode.

A choice of functions (ECG, PPG, BIA, GSR and SKT):
Algorithms are available for easy implementation of heart rate, skin temperature, emotion recognition, and body fat calculations, based on high-quality biosignals from the Bio-Processor. OEMs can use all of these algorithms or a selection, depending on their needs. In addition, Samsung is developing more advanced algorithms to report holistic health status using its unique AFE combinations.

Customizable health algorithms:
A software development kit (SDK) is available, including sensor APIs and compiler support for device makers and application developers to create their own algorithms.

Compact size for wearables (5.7mm x 4.9mm):
Space-efficient packaging enables flexibility and discreetness in device design.

Cost competitiveness:
A competitive price makes disposability of the Bio-Processor a viable option for sports wearables such as compression sleeves, kinesiology tape, and loaner gym devices, as well as medical devices such as patches and wristbands.

Robust security:
Data is protected by a True Random Number Generator plus Advanced Encryption Standard (AES) encryption of up to 256 bits.

Reference Device for Capturing User’s Bio-Data
To show the possibilities of the Bio-Processor, Samsung has created a reference wristband called Margaux Lite with an easy-to-read display, seamless data collection and fast recharging. The Bio-Processor handles all processing required, from powering the wristband to running the algorithms. Margaux Lite captures BIA, ECG, PPG, GSR, and SKT data via embedded sensors, and transfers data to a smartphone through a secure Android app.

Samsung continues to develop more reference devices to inspire customers and partners.
The Future of Remote Monitoring with the Samsung Bio-Processor

Samsung Bio-Processors are unlocking the next generation of innovative wearables, providing more and better ways to capture and analyze health data in real time. Their small size and compelling features are designed for consumers who have exhausted conventional wearable capabilities and desire more meaningful information. High-risk conditions can be quickly identified by alert algorithms, informing decisions made at home, on the town, or at the hospital admission desk. Health and fitness data can also be trended and baselines established, with the results securely shared among family, friends, and health providers. These improvements enabled by the Bio-Processor will significantly improve user wellness and health costs.

Potential Bio-Processor solutions will include:

Smart clothing — Smart clothes, earbuds and jewelry are ideal targets for Bio-Processors to capture biodata in attractive, comfortable designs. These products will be ideal for fitnesswear, and over time unlock new innovations in everyday clothing.

Smart bands and watches — The Bio-Processor can power these devices standalone, or be a companion to a separate processor like the Samsung Exynos. Future Bio-Processors will be even faster, capturing and integrating more sophisticated biodata, for truly holistic user health analysis.

Smart glasses — MCUs and application processors enable exciting augmented reality (AR) applications. The Bio-Processor can take the place of MCUs, introducing health monitoring into AR to foster new innovations in user interaction.

CONCLUSION:
REALIZING THE QUANTIFIED SELF

Samsung has transformed mobile devices the world over. We are now revolutionizing self-health assessment with the Bio-Processor — a secure, low-cost, low-power, and accurate monitoring solution. Our Bio-Processor offers efficient performance and a small footprint with top-notch security for maximum cost containment by device makers. It can operate as a co-processor or as a standalone processor for added versatility. These features will transform wearables, making them more compact, powerful, and useful.

Be sure to request a trial of the evaluation board, Margaux Lite, or other reference devices.

You can contact your local Samsung sales representative, or email us for more information at slsi@ssi.samsung.com.