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A HEALTHY FUTURE WITH WEARABLE SEMICONDUCTORS

With cost of medical care on the rise there is a need for solutions that allow patients to return home faster from the hospital. But patients also need the assurance that they are being remotely monitored through the period of step down treatment. Lightweight and inexpensive wearable medical devices that monitor remote patient conditions and transmit data securely to qualified teams and automated health systems are the solution. Such devices are increasingly becoming available, with innovation in the medical device industry enabled by the semi-conductor industry.

The changing pulse of medical care

Arrhythmias are transient events. Most arrhythmias – where the heart beats too fast, too slow or with an irregular rhythm – are reasonably harmless. But some can be life threatening. During an arrhythmia episode, the patient's heart may not be able to pump enough blood to the body. The lack of blood is known to result in brain damage and other organ failures. Arrhythmias can be treated successfully and most patients can hope to lead a normal, anxiety-free life. The difficult part is in monitoring the condition. Traditional ECG monitoring of a cardiac patient may not establish a reliable diagnosis unless the patient experiences an event during the recording. For a reliable diagnosis, the patient must

be monitored continuously. Medical researchers have developed a range of ambulatory techniques to address the challenge. These are good techniques that have been around for decades. But are they great? Are they simple? Do they serve the best interests of the patient? So far, the answer has not been a resounding "yes". If anything, it has been an uncertain "maybe". Now, the medical device industry is addressing the challenge by creating simple wearable medical devices. Mobile development combined with advances in semiconductor technology are making these devices portable, accurate, reliable and in several instances, cheaper.

The medical device and the semiconductor industries have sensed that health costs in the western world are rising and there is a need for a solution that brings down cost of medical care. Today, with tremendous pressure on medical infrastructure, the average length of stay in hospitals is dropping. For nonfederal short-stay hospitals in the US it has fallen from 6.4 days in 1990 to 4.8 days in 2009-2010 across all ages[1]. But patients benefit from continuous monitoring of critical signs, even after leaving the hospital, and allow doctors to respond quickly to situations and emergencies. Remotely monitoring the patient helps patients leave potentially-expensive hospitals faster and also improves the quality of step-down care.

Wearable Devices

There are several advantages of the new range of wearable medical devices that are emerging. They allow medical providers to offer preventive monitoring to the aged, for chronic disease management and general wellness. Remotely monitoring those who may be susceptible to illnesses like cardiac disorder before catastrophe strikes can bring down the need for hospitalization and subsequent medical costs.

Expectedly, the demand for these devices is growing. The market for them is forecasted to hit $20 billion by 2018[2]. A major chunk of the revenues will go to manufacturers of semiconductor components and embedded systems like memory, displays, processors, sensors and connectivity solutions that go into these devices.

Technical parameters

Wearable devices that work outside the confines of the hospital without expert medical assistance must fulfill a number of characteristics:

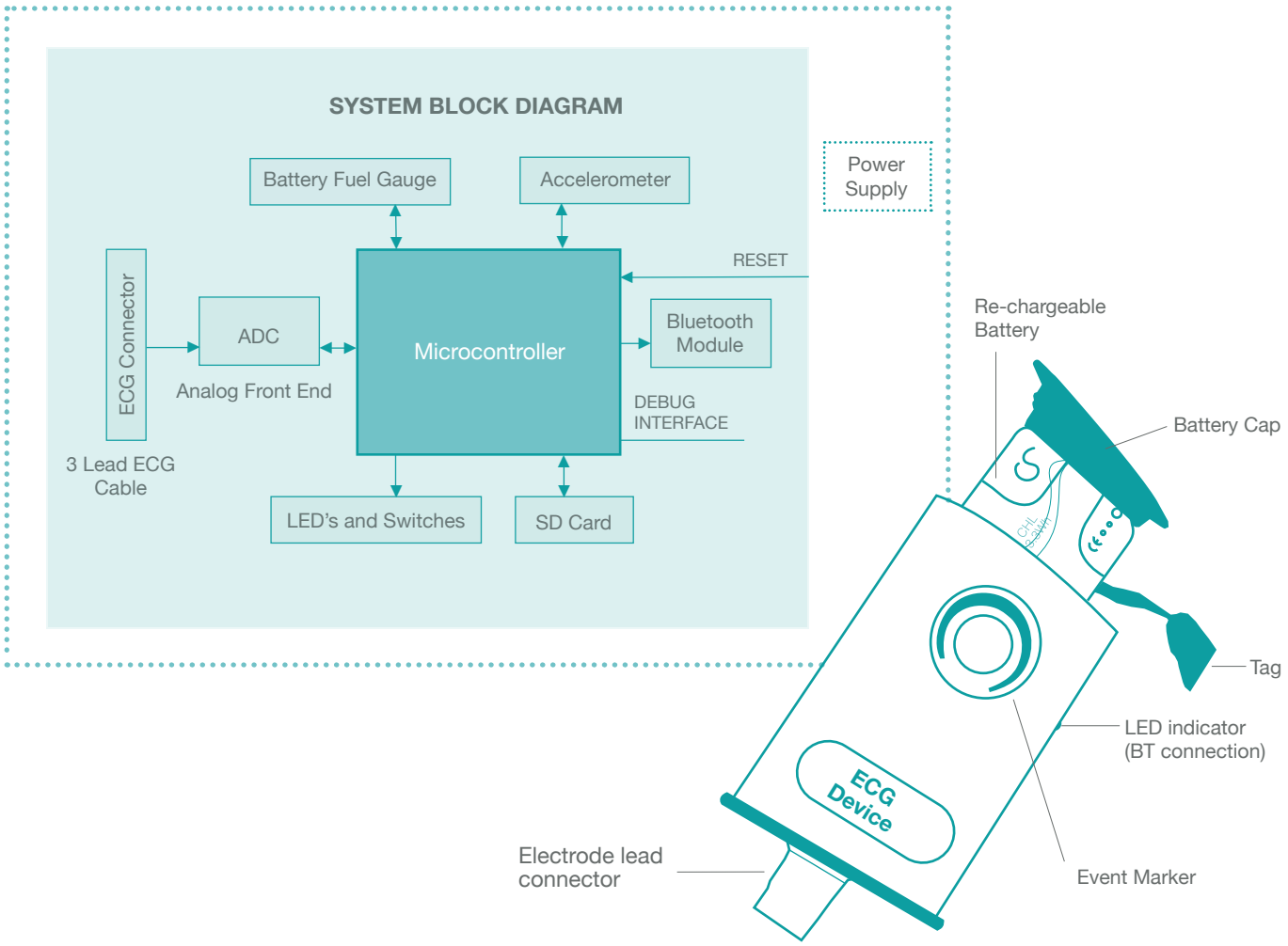
- **Usability:** The device has to be worn on a continuous basis and must therefore be small and lightweight. The challenge is to compress the device size down.
- **Power consumption:** The device should have low power consumption, reducing the need for frequent re-charging and disruptions in monitoring.
- **Design:** The device must be elegant without the need to attach long wires and electrodes from the device to the patient and from the device to the mobile gateway that transmits data (to the remote medical care unit).
- **Cost:** If a patient is required to purchase the unit, it should cost sub US$200 to be affordable or for the hospital to give it away free as part of medical care.

Devices that fulfill these conditions can expect to become popular. Manufacturers will find that users are able to easily integrate such devices into their daily lives for maximum benefit.

The typical set of parameters that the device must monitor include heart activity, fetal heart rate, skin resistance, skin temperature, refractive index of blood etc. Based on what the device is required to measure and monitor, its components would include:

- **Bio sensors**: Application specific bio sensors that emit signals indicating measured parameters
- **Analog-to-digital converters:** Application specific analog front end to digitize the sensor signals. The device may also be equipped with signal conditioning circuitry.

Fig1: ECG Device Block Diagram



• **General purpose micro controller:** To process signals for the device to function. Signals could indicate battery levels, failure, etc. or signals received from accelerometer, displays and switches, memory and connectivity solutions.

• **Wireless interface:** In most instances, the device will connect to a mobile gateway over a Body Area Network (BAN) or the newer Bluetooth LE (low energy) suitable for continuous transfer of medical data.

• **Memory:** In modern wearable devices, the data is sent in real-time to a mobile gateway (smart phone or a tablet) and then to the patient's remote health care provider. These devices can also store data in off line mode, synchronizing the data when the device goes online.

• **Power management:** The device design must ensure that energy consumption is minimized for longer uninterrupted device deployment and stand by time.

SOCs (System on Chip) engineered for wearable devices have begun to emerge (ex: Cypress Programmable SOC and the Intel Quark). These SOCs are often application specific and integrate all the components and systems of the device such as processors and memory. The analog front end which incorporates application dependent signal conditioning functionality is the key to the wearable device. Bearing in mind the importance of the analog front end, semiconductor companies have begun to devise special front ends to meet industry needs. The next generation of programmable SOCs is also expected to integrate Bluetooth Low Energy (BLE) to complete the wireless communication layer.

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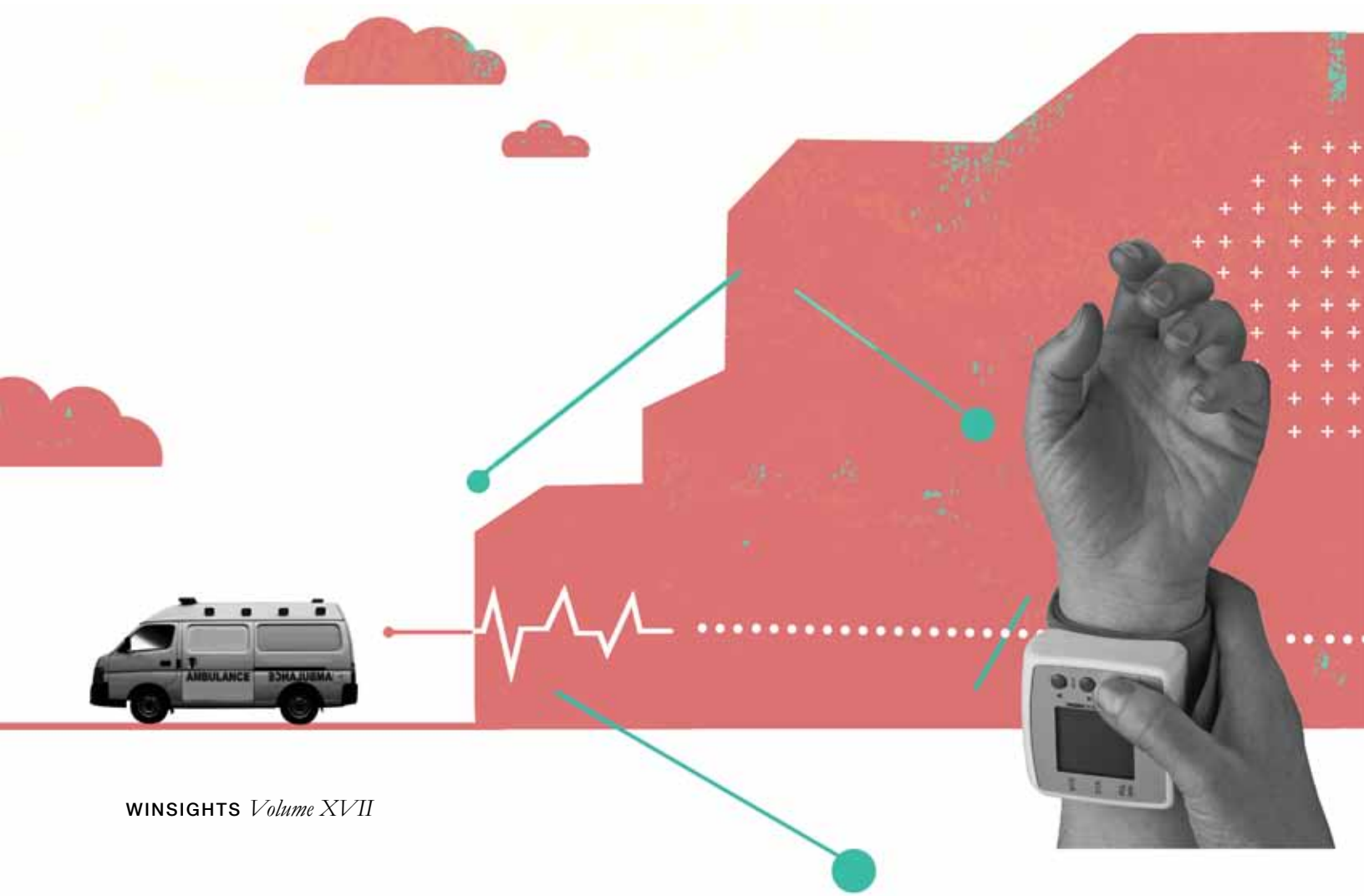
As medical devices begin to cater to a number requirements, their data collection and processing power also needs to go up proportionately. However, implementation of such functionality using discrete components can result in an increase in the Bill of Materials (BOM), device size and power. This can end up



killing the device during actual deployment as they will inevitably face resistance from users.

Can components be eliminated or minimized to bring down the cost and size of the device? Custom SOC solutions integrate an embedded CPU with a low energy wireless interface and application specific analog front ends. The solution involves significant upfront (NRE - Non-Recurring Expenditure i.e. One time development cost) investments as a part of the development process. Of course, solutions created using off-the-shelf components will involve a lower NRE but are clunky when compared to custom SOC solutions (which are typically small and lightweight). However, if the volumes for wearable devices increase, the custom SOC solutions become a preferred path to adopt.

In addition custom SOC solutions offer the advantage of being tamper-proof or copy poof. The critical algorithms that a medical device provider comes up with can thus be protected. It is also a very popular route to creating a solution because of the security it offers as talking to implantable devices is risk prone and requires the highest attention to data security.

The heartbeat of the revolution

The impact of an unobtrusive, easily usable, accurate, reliable and wearable medical device that can store/ transmit high resolution data for long uninterrupted periods (approximately 30 days) over a mobile gateway to remote medical monitoring and analytical systems can be immense. If the device is capable of some local processing using applications on the mobile device, its value is further improved. And finally, if the application on the mobile device has intuitive audio/ video capabilities that enhance intervention from the remote care giver, the solution is guaranteed to succeed. Amidst this, the growing role of researchers, chip designers and fabricators in the semi-conductor industry cannot be underestimated.

1.US Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics: *http://www.cdc.gov/nchs/data/hus/hus12.pdf#097*

2.Markets and Markets, July 2013: *http://www.marketsandmarkets.com/Market-Reports/semiconductor-opportunities-mobile-healthcare-market-1204.html* ■