The WearARM: Modular, High Performance, Low Power Computing Platform Designed for Integration into Everyday Clothing

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Abstract

This paper describes a low power, high performance wearable computing plattform, specifically designed for easy integration into everyday clothing. It combines a heterogenous, distributed, user reconfigurable system architecture, advanced power management features and highly miniaturized, mechanically flexible electronic packaging technology. As a result the WearARM system offers high perfomance for a wide range of application in a form factor that allows it to be worn without in any noticeable way interfering with your look and comfort.

1 Introduction

Today there are five main types of wearable computer hardware: wrist computers (see http://www.ruputer.com/english/product, [6]), smart badges (e.g. [7]), PC-104 plattforms (e.g. http://www.jumptec.de), notebook/convential PC based platforms (http://www.xybernaut.com,[1]) and palm like, credit card sized boards and systems. Each of these system types satisfy a different set of requirements for wearable computing. On one hand there are computing platforms supporting high performance, medium power consumption, flexibility and ease of configuration (e.g. MIT Lizzy or Lart [2]) that are suitable for a wide range of wearable applications. However they are essentially rectangular, solid, fairly large and ill suited for integration into the user's clothing. On the other hand there are devices like smart badges [3] or computing modules with the power comparable to an average PDA [4], [5]. They have been successfully implemented as thin, sub credit sized modules that can easily bland with the users every day clothing. Unfortunately such devices provide neither the computer power nor the interfaces necessary to support high performance wearable computing needed for augmented reality, speech to text, text to speech and gesture recognition.

The WearARM combines the computation power and interface capability of a notebook like plattform in a form factor which allows to seamlessly blend into everyday clothing. The key design aspects that allows us to achieve this are:

Distributed Architecture: The WearARM architecture relies on a low power embedded processor for general purpose processing combined with low power DSPs and special purpose circuits for computationally intensive tasks. This allows it to facilitate computing currently reserved for power hungry PC like hardware at a fraction of their power consumption.

User Reconfigurability: To achieve the required versatility the WearARM system consists of two parts. The first one is a two module core system built around a low power embedded StrongARM processor and few most important IO devices and interfaces. The second one is a theoretically unlimited number of peripheral modules that can contain anything form interface connectors through IO controllers to DSPs and additional processors.

Advanced Power Management Support: The WearARM system supports software-controlled dynamic voltage scheduling (lowering of processor supply voltage inline with the operating frequency). In addition it provides meassurement points for power consumption profiling of individual components.

Advanced Electronic Packaging: The WearARM components have been implemented using a high density substrates allows to keep use the size of each module below credit card. For interconnection between the modules we use FLEX substrates and high density connectors. This allows the system easily fit in the everyday clothing.

2 Architecture

The WearARM in typical configuration has four modules [figure 1]: core, basic, peripherie and vision module. The modules attached offer several interfaces to enhance the core module to a easy to use computer.

The next paragraphs will describe the implemented modules. Depending on the application further modules (including additional processing modules and DSPs) could be added or used to replace the default ones.

Core Module

The core module contains the SA 1110 CPU, SA 1111 companion chip, SDRAM, Flash and VGA DAC. The WearARM core module is in principle a fully functional computer. All it needs from the outside is power supply, the connections to the required input/output devices and for some interfaces signal level shifters.

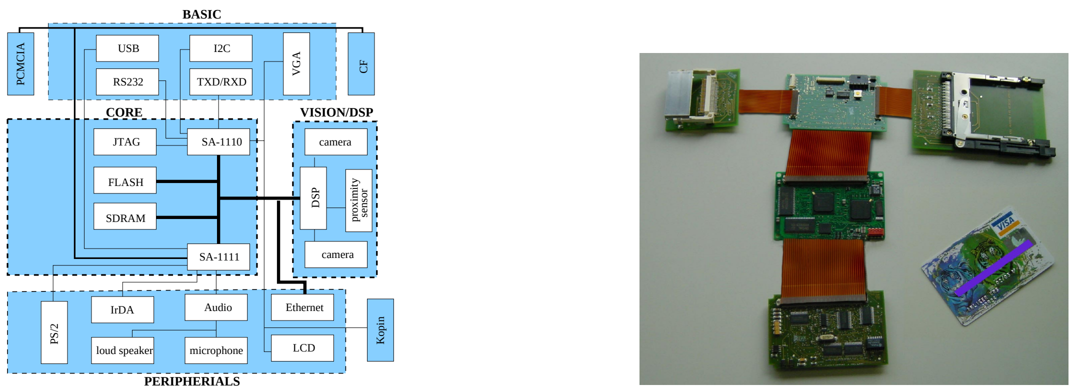

Figure 1: left: block diagramm right: possible configuration with FLEX conections

Basic Module
The Basic module offers power supply to the core module, RS232 level shifter, I2C bus extender and signal prepartion for the CF and the PCMCIA socket. The PCMICA and CF module are attached to the BASIC module with FLEX connections. A USB master and VGA output with the needed serial termination is avible on a connector.

Peripherie Module
The desgined peripherie module contains extented features, which include 10 baseT Ethernet (for body area networking), a audio systems for speech control and audio output, several interfaces as IrDA, LCD and PS/2 and buffers on the memory bus to allow further modules to be chained without overloading the bus drivers, accessible through the 100 PIN connector.

Vision/DSP module
The Vision module is connected on the buffered memory bus. It has been designed for wearable gesture and image recognition. For the computation intensive task the module contains a low power Texas Instruments DSP, a 4 Bit Flash with boot sector, two cameras and a proximity sensor. The DSP can be also used for other computation intensiv task such as realtime filtering.

Power Management Infrastructure
The SA-1110 offer beside standby and sleep modes also dynamic voltage scheduling. The operating frequency can be reduced in 10 steps from 206 to 59 MHz. The WearARM System supports this dynamic voltage scheduling by a sofrware controlled external voltage source and also supports extensive power profiling for individual components.

For precise runtime measurements of power consumption the WearARM contains special contacts where we can measure the current drawn by the individual system components.

3 Applications

The WearARM system is predominatly intended as a research platform. The combination of high performance and flexible configuration with easy integration into everyday clothing makes it perfect for long term field studies under real life conditions. At the ETH we will among others investigate the use of context data for power management. The MIT group will integrate the WearARM into its MIThrill (http://www.media.mit.edu/wearables/mithril) wearable system und use it for research on social interaction. Apart from research the WearARM platform has many potential uses in wearable appilcations including firefighting, hazardous materials construction and manufacturing.

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