Kristyn DiGiovanni
Project Advisor: Dr. Hasler
Music Synthesis with FPAAs

Embedded Processors in Systems

Introduction

Embedded systems involve controlling a network of signals from various external devices to create a cohesive yet compact product. Increased demand for broad functionality makes the versatility of embedded processors incredibly desirable in today's market. The role of embedded processors encompasses managing the input and outputs involved in these types of systems. This paper reviews commercially available low-power embedded processors and applications, the technology developed upon, and implementation methods in systems.

Commercial Applications of Embedded Processors

The rapid growth of technology in the last decade fuels the need for low-cost, low-power processors to provide the advanced functionality required in today's commercial market. Applications include smartphones, refrigerators, planes, elevators, and more. Processors are chosen based on requirements of the system it is controlling, and as such there are numerous variations of embedded processors. Companies such as Texas Instruments and NXP Semiconductors compose a large percentage of the global market who produce these embedded processors [1].

Texas Instruments

Texas Instruments produces two main series of low-power processors. The first is TMS320C674x, a 256 kB TI-RTOS processor which costs approximately $6 per unit. Implementations incorporate music effects, machine vision, and radio due to the advanced digital signal processing core within [2]. The other principal low-power embedded processor produced by Texas Instruments is the OMAP-L138 which integrates a digital signal processor with an ARM processor for approximately $9 per unit. Total on-chip memory size is 448 kB, and it runs a Linux TI-RTOS operating system. The added functionality of the ARM processor expands possible utilization to include industrial applications, including portable navigation devices and automation [3]. Both processors contain hardware and software flexibilities to allow conformity within the hardware specifications and demands of the system and include the software development and debugging platform Code Composer Studio to aid in programming.

NXP Semiconductors

NXP Semiconductors also produces two families of general-purpose low-power embedded processors: the i.MX2x and the K32. The i.MX28 contains 125 kB of on-chip memory, up to 289 pins, and clocks at speeds up to 450 Mhz [4]. It costs approximately $9 per unit, and its hardware is optimized for general embedded industrial and consumer markets while aligning most with applications such as human-machine interfacing, handheld scanners and printers, and energy gateways [5]. It runs on a Linux system, and an embedded software support package is provided to use in development. The K32 L3 is the ultra-low-power general processor developed by NXP. It utilizes the Cortex-M4/M0+, contains 1.25 MB of flash memory, 176 pins, and a low-leakage design [6]. Target applications for the K32 L3 include building automation, and industrial and smart home devices [7]. It costs approximately $7 per unit. NXM provides an embedded software development package with the K32 L3 called MCUXpresso to drive and program the processor.

Technology Involved in Embedded Processors

Embedded processors are composed of transistors to form modules including an Arithmetic Logic Unit (ALU), a memory unit, a Control Unit (CU), a set of registers, a system bus, and peripheral devices [8]. The system bus encapsulates an address bus, data bus, and a control bus, all of which provide electrical conductivity between the controller and peripheral devices and the memory unit [9]. A processor's memory unit can be composed of many different forms of memory, such as RAM, ROM, DRAM, and Flash depending system requirements. It is arranged in a stack so that software, hardware, or a combination of software and hardware packages can simulate the appropriate memory and architecture for the system [9]. Finally, the Control Unit is composed of a logic chip which manages the operations of the other modules. This logic chip is coupled with these modules to guarantee all data flow is directed through the CU for proper control of instructions and signals [9]. All of the modules are integrated through transistor connections to form a single cohesive semiconductor IC. The processor is then embedded into the overall system and programmed using software development tools to perform operations.

Future

Transistors within processors now range in sizes between 6-15nm. Constraints in the fabrication of embedded processors will soon arise as Moore's Law predicts a halt in the reduction of sizes of transistors. Companies' focuses are shifting toward optimizing power-efficiency and software development tools included with their processors to break through the power and performance walls associated [10]. Before-mentioned implementations involve the application of parallel multiprocessors and architectures, employing 3-D transistors instead of the previous planar structure transistors for pipeline stages to be vertically stacked on top of each other, and utilizing low-k dielectrics to reduce coupling capacitance and therefore transmission delays [11].

Implementation of Embedded Processors

Selection of an appropriate embedded processor is tailored to the demands of the system. Factors include cost, peripheral set, memory size, performance, and programmability [12].

Hardware

Many hardware aspects determine the appropriate implementation of embedded processors into systems. Two such factors are communication interfaces and the number of digital inputs and outputs [13]. For example, if a system requires 20 total I/O peripheral devices, the processor needs enough pins to support those devices and must contain the computational power to handle all of those signals. Architecture is also vitally important in determining a processor. Processing and computational power restrictions occur if architecture is not acknowledged [13]. For example, if floating-point arithmetic is executed in the program, the embedded processor architecture must contain functionality to support it. Memory availability, such as the size of Flash and RAM, are also important in the implementation of embedded processors [13]. From the architecture chosen, estimated program size, and the number of peripherals used, appropriate memory size can be determined. Estimating desired memory sizes beforehand helps prevent limitations due to a lack of resources later in the development process and product life [13].

Software

The main software requirement in implementing embedded processors into systems is the programming and driving of the processor itself. Implementation in software is specifying how the system performs tasks and ensuring that all software modules associated with that implementation can be integrated to form a cohesive system [14]. Manufacturers often provide development kits in addition to the processor to do so, exemplified by the processors described in the Commercial Applications of Embedded Processors section above. Most embedded processors are coded in C++ and are aided by content libraries to help integrate external devices into the system. The designer needs to choose the development kit appropriately to ensure that all parts of the system can be programmed desirably.

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