Proceedings of 30th Indian Engineering Congress, the 21st Century Engineering: The Make in India Pathway, *December 2015,* pp.129-133

Embedded Processor based System Design: A Brief Overview

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Abstract

With the technological developments in the advent of microprocessors, the embedded systems have become an everyday reality that allowed single chip processors to control and monitor the industrial process independently. The embedded systems are more flexible, economical, and easier to design and upgrade. This paper describes general aspects of embedded systems, analyzes their status and future market trends. This also explains the present design trends with difference between embedded processor and desktop processor. Finally, the application of embedded processor in the industrial process control has been demonstrated in the paper.

1. Introduction

With the technological developments in the advent of microprocessors, the embedded systems have become an everyday reality that allowed single chip processors to control and monitor the process with flexible and inexpensive way. Consequently, microprocessor based embedded systems have been introduced into many new application areas. Currently, embedded system based on programmable microprocessors, digital signal processors and RISC processors, are frequently used in consumer electronic devices, home appliances, automobiles, network equipment, industrial process control and monitoring the system, etc. The growth of application of embedded systems appears to be exponentially as shown in Figure 1. This shows demand and future market projections of embedded processors and how it outpaces those of PC processors after 1997[1]. It can be observed that demand of embedded system was less in 1996. This is due to less awareness among the customers about the applications embedded system and embedded systems were under design and development stage. In 1997, the sale of embedded processors was almost equal to the sales of PC processors. After 1997, the sale of embedded systems was higher than that of PC processors.

and is showing a much higher growth rate. In contrast, PC processors are only showing a gradual growth. The rapid or faster growth of the embedded system is due to the demand of computing technologies in the field of medical science, automotive industry etc. which is accompanied by faster advancement in VLSI technologies and tendency to replace analog processing with digital processing.

The paper is organized as follows - Section 2 gives an idea of embedded systems in general, it also formulates our definition of an embedded system. Section 3 gives the requirements of such systems

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and categorizes them. Section 4 gives an idea about the essential parts of an embedded system. Section 5 gives a description to embedded processors by stating their characteristics. Section 6 gives a conclusion by stating some design trends of embedded processors.

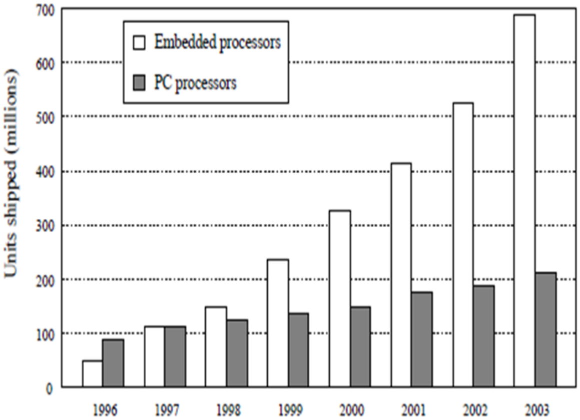

Figure 1. Marketing projections of Embedded Processor with that of PC processor.

2. Embedded System

In general, a digital system can be designed for general purpose or for specific applications. The general purpose systems are not customized for any specific application rather they can be programmed by the end-user to perform a broad range of different applications. For example general purpose systems include: desktop computers, notebooks, workstations, etc. On the other hand application specific systems are designed for dedicated applications, hence cannot be efficiently used for other application. Such application specific systems may be used in home appliances, consumer-electronic devices, medical instrumentation, process control, networking and telecommunications, etc. Hence, the embedded systems are the application specific systems, usually contained within a larger and often non-electronic systems and the larger systems which are the embedding system, which is usually an external process typically comprising of both a physical system and a human operator. The general embedding model is graphically depicted in Figure 2, where it can observe that the embedding system is communicating with an external environment. Thus, an embedded system can defined as a computing system built into a larger system, designed for dedicated functions. It consists of a combination of hardware, software, and optionally mechanical parts. Thus the term refers to any computing systems other than general purpose PC or mainframe computers[2].

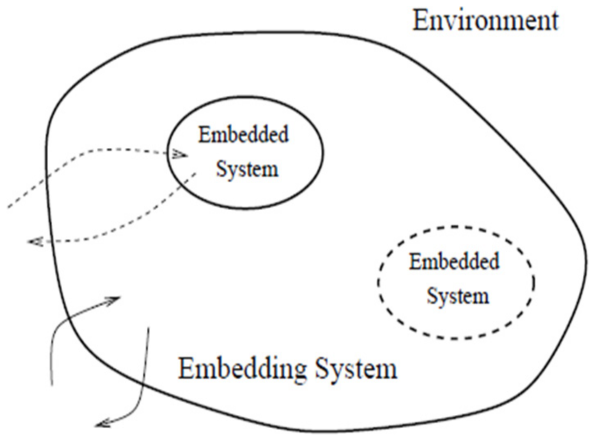

Figure 2. General Embedding System Model.

3. Requirements of an Embedded System based Process Control and Monitoring

The requirements of an embedded system is characterized by its immediate environment or the embedding system. Still they can be classified on the functional, temporal and dependability requirements background. The functional requirement of an embedded system is the operations that it needs to perform which are determined by the services required by the embedding system. These services can also be referred to as applications as perceived from the embedded system's point of view. The functional requirement can be further sub-divided into three categories as – Data gathering, Data Transformation, and Control.

In Data Gathering the main function is to obtain information from the embedding system or from the environment surrounding the embedding system. Generally the data gathering task is performed by the sensors or receivers. In the case of sensors, the analog data must be first converted into a digital one after which a limited set of operation must be performed before storing the data. Now the Data transformation is performed on the gathered (digital) data in order to display or to send, etc. Some transformation operations include: compression/decompression in order to limit storage space or to decrease transmit time and encryption/decryption in order to protect the gathered data. Now lastly, Control is performed based on the (transformed) data, and hence a decision is taken to act on the environment depending upon the transformed data.

Again many embedded systems may also have to deal with temporal requirements which occur due to the fact that some tasks have deadlines. Again the deadlines are of two kinds - hard-deadline and soft-deadline. In hard real-time deadlines, the system has to deliver the service before the deadline i.e., the task has to be completed before the deadline. All the tasks with hard real-time deadlines are critical and a failure to complete before the deadline can have serious result whereas the situation is quite opposite while dealing with soft real-time deadline. In this case the essential task can be completed even when they cannot be delivered before their deadlines.

The last requirement, in relation to embedded system is the dependability requirement. The dependability requirement is basically the quality of the service provided by the embedded system to the embedding system during an extended interval of time (life time). Again the dependability or the quality of the service can be measured as: Reliability, Maintainability and Availability. Reliability is a probability measure indicating the operational time of an embedded system within a certain span of time. Maintainability is a measure of the time to repair a system after the occurrence of failure. Availability is a measure of the fraction of time that the embedded system is available to provide its services to the embedding systems with respect to the total time, i.e. the time in usage added with the time to repair the embedded system.

4. Essential Parts of an Embedded System

The generally accepted essential parts of an embedded system is as depicted in Figure 3.

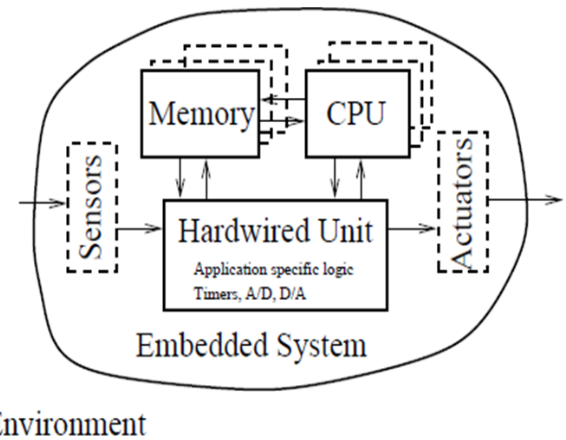

Figure 3. Essential Parts of an Embedded System.

So an embedded system contains essential parts as - central processing unit (CPU), a memory, and a hardwired unit. These three components form a minimum hardware support that an embedded system needs in order to provide a specialized service to the embedding system. The sensors and actuators are shown dashed line boxes to suggest the fact that though they are present in a large number in real life embedded systems but they are optional components. However, we included sensors and actuators in Figure 3 as potentially essential parts because a large number of practical embedded systems designs include such components and even if the system do not contain them it has to contain other modules to interface the embedded system with the embedding system and/or the environment. The embedded system can communicate with the environment (embedding systems) directly, for example the case for an I/O processor embedded into a workstation.

5. Characteristics of an Embedded Processor

The first and the most important characteristics of an embedded processor is that they are application specific processors and hence are definitely not general-purpose processors. Again in this kind of system the characteristics of the job are known before the design of the actual hardware which opens the road for hardware/software co-design i.e., the cooperative and concurrent design of both hardware and software components of the processor.

Another important characteristic of embedded processors is its static structure, i.e. the end user has very limited access to programming. The software is provided by the application developer, which resides on the ROM memories and runs on processors which are not accessible to the end user. The user cannot change (reprogram) the basic actions of the processor, but only can program the processor to perform a sequence of basic actions.

The embedded processors are essentially nonhomogeneous i.e. heterogeneous processors and this characteristic induces the process within which the processor is embedded for both analog and digital sub-processes which may be required in the system. The hardware may include microprocessors, micro-controllers, DSPs, ASICs, FPGAs, etc., and the software may include various software modules as well as a multitasking real-time operating system.

6. Trends and Research Direction

Now, it can be observed from the previous discussion that there is a considerable shift in programmable embedded processors. While the simple fixed function processors are still abundant and many specialized hardwired embedded processor units still exist and required due to customer demand. This is because of its advantages over its predecessors.

Advantages of programmable embedded processors are identified as follows: The embedded systems are more flexible, easier to upgrade and differentiate from a previous design. The change in specifications can be included. It is possible to re-use of earlier designed software modules (functions) assuming that they were described at a processor independent abstraction level. This paradigm shift has as a side effect the migration from assembly to high level languages (in particular C). Hence the trend is expected to continue in the future for two reasons. Firstly, the industrial fight for market share in the growing embedded processors market for increasingly demand for shorter time-to-market windows. Secondly, the heterogeneity of many systems requires many embedded processors within one embedding system with each one having their own design cycles. This situation is increasingly becoming undesirable as these design cycles are hard to control and to synchronize and thus delaying the completion of the overall system. Utilizing a smaller set of embedded processors and performing a wider range of services (e.g., via programming) is therefore becoming more desirable. This has to be multiplexed/ overlaid with the increased usage of reconfigurable hardware extending the previously mentioned need for programmability in embedded processors. Configurable hardware structures performance is likely continue to increase in the future, making it a good option over fixed hardware structures. Examples of architectures supporting reconfigurable hardware are in [5–10].

The advantages of programmability in embedded processors are evident, but the danger exists that functions performed by such embedded processors are too generic and thus decreasing performance. We envision a third trend that entails the definition of complex functions specialized for the application and their incorporation into embedded processors. Examples can be found in [11–13].

7. Conclusion

It is concluded that the embedded processors till date are based on manual design and early experience with similar products. However, this is expected to change in the mere future, especially taking into account that future embedded processors to be more programmable. Some potential fruitful research directions related to embedded systems design are describes as follows:

- Embedded processors: Application specific instruction set processors (ASIP), parameterizable processors, reconfigurable computing.
- Retargetable compilers: System modeling, synthesis, and design space exploration.
- System certification and performance evaluation.
- Hardware/software co-design (Maybe the most mature embedded systems related field but still a lot of effort has to be done in this direction).

8. References

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