SIXTEENTH EDITION

ELECTRICAL ENGINEER'S REFERENCE BOOK

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Sixteenth edition

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15.1 Introduction

Digital systems are used to process discrete elements of information. They are built from digital electronic circuits that process discrete electrical signals using simple logic and arithmetic operations. A digital electronic system can also be used to hold or store discrete elements of information and this gives the system a memory capability. The ability to store information or data and to process the data by logical or arithmetic operations is central to the design of nearly all digital information-processing systems including digital computers. The function of a digital system is determined by the sequence of operations that are performed on the information or data being processed. A digital system can be classified by the way in which its sequence of operations is implemented.

A digital system is considered to be hardwired if the sequence of operations is governed by the physical interconnection of the digital processing elements. For example, in hardwired logic systems the physical interconnections of the elements govern the routes by which data flows between the processing elements and thus the sequence of processing operations performed on the data. Conventionally, a hardwired system is considered to be inflexible because the design is specific to a particular processing function: if the processing function is changed, then the processing elements and their interconnections have to be altered.

The flexibility of hardwired systems has been much improved by the introduction of programmable (i.e. configurable) logic devices such as Programmable Logic Arrays (PLAs) and Field Programmable Gate Arrays (FPGAs) that can be programmed or configured to implement an application-specific digital signal processing function. Flexibility has been improved further with the introduction of re-programmable (i.e. re-configurable) devices that can be reprogrammed easily during fast-prototype system development, and can be reprogrammed after a product has been deployed to provide enhanced features or performance. Progress in this area has been rapid and the latest generation of re-programmable FPGA device can be configured with a wide variety of communication interfaces. This opens the possibility of using advanced communication technology, such as the Internet, to re-program or re-configure a remote hardwired system.

A digital system is considered to be genuinely programmable if a prescriptive program of instructions (i.e. software) can be used to control the data-processing function of the system. This type of system usually incorporates a general-purpose processing element which is programmed to implement a specific function in a predetermined way. The coded instructions are normally stored in the memory part of the system and the program forms an integral part of the system. The ability to define the function of the digital system by programming introduces considerable flexibility into the system because the programming operation can take place after the general-purpose digital elements have been designed. It also means that identical hardware designs can be used in a number of different applications, the system being tailored to the individual tasks by the applications program. A wide range of simple fixed-function programmable systems, such as sequencers and microprogrammed controllers, are used as controllers in embedded electronic systems. In this type of application the sequence of instructions is usually held in read-only memory (i.e. firmware) which increases the robustness of the system.

The digital computer is a very important class of stored

both the prescriptive sequence of coded instructions and the value of the data being processed. In effect, the program prescribes a number of possible sequences of operations and the conditions under which they may be carried out. The computer, under program control, assesses the data and determines which specific sequence of instruction is to be executed. It is the ability of the computer to take into account the value of the data being processed, when taking decisions about the type of processing to be performed, which makes the computer such a significant and powerful information-processing device.

All three forms of digital electronic system find widespread application. Traditionally hardwired logic has been used extensively to provide the control and interface logic for more complex digital components such as microprocessors and other very large scale integration (VLSI) devices. It is also used in the design of high-speed signal processing circuits for FPGA implementation. Increasingly, hardwired logic is used to provide the interface circuits between the main functional components within a complex FPGA. Where flexibility is required, it is common to use reconfigurable systems particularly in more complex applications.

Programmable systems are used in an extremely large range of applications. The simpler fixed-function programmable systems are often used in repetitive tasks such as input scanning and data acquisition. They are also used in mass-produced products and as components of larger systems such as telephony equipment. However, the continually increasing computational power of the microprocessor and its derivatives, such as digital signal processing (DSP) devices or powerful reduced instruction set (RISC) processors, has led to many of these applications being designed using fully programmable digital systems. In addition, commercial off-the-shelf (COTS) microprocessors are commonly used in both stand-alone and embedded systems. Such systems are providing economic solutions to design problems in an increasingly wide range of application.

The increase in size of VLSI logic circuits has led to a new generation of reconfigurable devices that are large enough to contain a complete digital processing system within a chip, called System on Chip (SoC) devices. An SoC device can be configured to include an embedded digital RISC processor, memory, communication interfaces, clock management, application-specific digital signal processing (hardwired logic functions), and appropriate internal interfaces and data buses. This allows the designer to partition a design into those parts that will be implemented as software executing on the embedded processor and those parts that will be implemented in hardware as high-speed application-specific logic circuits. This design approach, known as co-design or co-ware, has the significant advantage that established and high-performance parts of the design can be committed to application-specific hardware, and more adventurous parts of the design or low-speed functions can be committed to easily changed software. This minimises risk, facilitates time-to-market which gives competitive advantage, and provides a good path to post-deployment upgrades of the system's capabilities and performance.

15.2 Structured design of programmable logic systems

The design of an application-specific digital system typically involves the so-called 'top-down' approach and starts from