15 - Field Programmable Gate Array Microprocessors

Field Programmable Gate Array (FPGA) Microprocessors are design-flexible and re-programmable integrated circuits that provide for facilitated microprocessor design and for re-confirgurable hardware.

Developed in the mid 1990s, FPGAs were originally developed for use used by the U.S. military in a number of computer prototypes with the first licences going to private companies in 1994.[1] This design was originally intended to be an aid to designers of integrated circuits to enable the design-test-redesign process to be facilitated.[2] What has happened since then is that the designers have begun using the FPGAs as the end products rather than the means to the end.

The market for these integrated circuits is estimated to be around $38 billion over the next five years.[3] This is nearly 10 per cent of the total integrated circuit market that is estimated to be around $416 billion in 2006.[4] While there are certainly some disadvantages with FPGAs, their use as embedded processors is increasing at a rapid rate.

Purpose of FPGAs

There are number of issues involved when planning and designing an integrated circuit. One is the time that it takes to get a product to market. Integrated circuits require many hours of development and testing. To build a new prototype microprocessor and put it into production can cost as much as $16 million. If difficulties are encountered once the chip has been produced, the costs of reworking the design for the developer can be debilitating.[5]

Many new microprocessors are developed using proprietary designs that are licensed from other developers. This provides for a much less expensive design process and draws upon proven designs and includes device specific improvements to meet the needs of the client. These types of microprocessors, Application Specific Integrated Circuits (ASICs), provide for high performance in the end and at a reduced cost (See Box 14.1 – Microprocessor Architectures).

FPGAs are able to overcome some of the issues of cost. On one hand they provide for the chance for a speedy test-redesign-retest process. Designers are able to trial their proposed integrated circuit in a "bench-test" situation. This provides for greater certainty once the microprocessors are into production. Alternatively, FPGAs allow for the integrated circuit to be re-programmed in the end device rather than replacement of the hardware. The U.S. National Aeronautics and Space Administration (NASA) used these microprocessors in unmanned space craft to allow for reprogramming as a result of the destruction by radiation of the irreplaceable circuitry.[6]

Technology

Every microprocessor has a number of discrete parts. The main component is the processor and memory units. In addition there are logic gates that "surround" the processor and it is these logic gates that are the focus for this technology. The FPGA provides for flexibility in the design of the function of the microprocessor in total but not so much in terms of the processor itself.

FPGAs come in two forms – soft and hard. The first is a "soft" processor where the FPGA is programmed to contain a processor from within its own components. The performance of this type of FPGA is very poor in comparison to custom-made microprocessors. However, the advantage is that if an FPGA is purchased from the manufacturer, the programming for the processor is included in the cost of the microprocessor. This allows for an inexpensive method of developing applications and for greatly improved flexibility in research situations.[7]

The "hard" FPGA processor contains an actual processor from another vendor. The advantage of this combination is that the client can have an FPGA that has a high-performance processor with programming abilities. This design is much faster than the "soft" processor and is designed to compete with Application Specific Integrated Circuits (ASICs – See Box 14.1). While these microprocessors will never have the performance of the high-end chips, when these are placed within the dynamic environments such as the automotive or communications industry these types of microprocessors have advantages that will provide for increased utility.

Current Applications

During the late 1990s, mobile telephone systems were being developed using the Global System for Mobiles (GSM). At that time the final standards for GSM were still being negotiated. As it was difficult to know what the final protocols would be, it was realised that a custom microprocessor could become redundant very quickly.

In the race to be first-to-market, telecommunications equipment manufacturers used FPGAs so that they would be able to up-date the changes in the GSM

standard in the product as it came off the assembly line. Additionally, this equipment could also be reconfigured on site using a remote access connection.[8]

DaimlerChrysler is producing top-of-the-range vehicles, including the Mercedes Benz SL, that contains many thousands of marks worth of electronics equipment for on-board performance monitoring, entertainment and communications. Normally the original design of the electronics equipment would have been planned years before the car comes off the assembly line. With the speed of change in communications protocols and continuing product development, automotive manufacturers are sometimes faced with out-of-date-equipment during delivery.[9]

FPGAs are able to be "flashed" (as termed by DaimlerChrysler) with the latest programs making the motor vehicle's electronic systems completely up-to-date. This flexibility extends further as the FPGAs can continue to be up-dated for years afterwards with program improvements. This is seen to be a competitive advantage and will require the service technician to become familiar with communications equipment thus requiring additional training.[10]

Future applications

Time-to-market is of critical importance for manufacturers of new products. Of equal importance is the flexibility of existing equipment that is able to be re-configured is important. These are features that appeal to both manufacturer and client and there is no reason why FPGAs would not be able to be used in other industry areas including process and manufacturing automation and in consumer electronics - especially television set-top boxes.

One main disadvantage will be that the performance of the FPGA will be lower than an Application Specific Integrated Circuit (ASIC) but the cost at around $3 - 10 is much less expensive than designing a custom chip and waiting for its production. The increase in the application of FPGAs will see not only automotive maintenance technicians becoming communications experts but nearly every other electrical and electronic related area requiring similar skills.

A inherent disadvantage is that FPGAs are not suitable for digital signal processors as these microprocessors do not have the ability to alter the necessary hardware required for measuring analogue signals. This presents some difficulty for the embedded processor market. The use of FPGAs in this area will continue to suffer from some difficulty but manufacturers of FPGAs[11] and other software and equipment suppliers[12] are working towards resolving these issues.

Summary

FPGAs will provide increased flexibility of design for manufacturers and users of microprocessors. The embedded processor applications are extensive. The ability to communicate with these devices and load new programs for increased functionality will see nearly all technicians requiring new skills.

IMPLICATIONS FOR THE SHARED TECHNOLOGY INDUSTRIES

Automotive

As demonstrated above, the automotive industry will be one of the major users of this technology. While manufacturers will be providing training early for high-priced premium automobiles, there will be continuing development in down-stream product offerings. This technology will provide enhanced product abilities thus increasing competitive positions but also enable lower costs for manufacturers.

In the commercial and industrial markets this technology has the ability to transform the performance characteristics of the vehicle. This will provide for greater efficiencies in performance that will be able to better suit the local conditions.

Building and Construction

Apart from building automation systems, this technology will have little impact.

Electrical

As Programmable Logic Controllers (PLCs) had a significant impact on electricians, this technology will have a similar impact. While the actual programming is likely to be done by vendors or specialists, the installation and test will need to be done by this type of technician.

Electronics

This industry will see the greatest impact from this technology. As the devices containing this technology will be serviced and maintained primarily by these technicians, there will need to be continuing professional development of existing operatives.

When combined with the ability to connect many industrial devices to a network, the assessment and re-configuration of these connected devices will be done increasingly through remote access capabilities.

Engineering

While not present in all process and manufacturing automation installations, some sites will benefit from the ability to be reconfigured for changing requirements. This technology combined with wireless communications can provide for highly flexible and responsive automation design.

Information Technology

Skills in loading new programming requirements will become increasing diverse as a result of this technology. Application software will need to be

developed to allow for user-friendly approaches that enable the easy interaction of users with these programmable devices.

Telecommunications

This industry will continue to benefit from the use of this technology. The dynamics of this industry will continue to experience rapid change and development. The large number of devices that are protocol-specific will need to be up-graded and this technology has already demonstrated that it is suitable for the task. Therefore technicians in this industry will continue to see the application of this technology in a wider range of devices.

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[1] See Annapolis Micro Systems http://www.anapmicro.com/aboutus.html Accessed: 19 April, 2003.

[2] Bains, S. (1996). Technology: Boards make smarter connections. *New Scientist*, 14 September, 1996, p. 21.

[3] Fenn, J., Walker, J., Ball, R., & Tully, J. (2002). *Hardware platform technologies from 2003 to 2012*. Gartner. Reference Number: SPA-18-8621.

[4] PricewaterhouseCoopers. (2002). *Technology Forecast: 2002 – 2004, Volume 2: Emerging patterns of internet computing*, p. 105. Menlo Park, CA: Author.

[5] *The Economist*, Bespoke ships for the common man, 12 December, 2002.

[6] Ananthaswamy, A. (2001). Space babies. *New Scientist*, 03 February, 2001, p. 26.

[7] PricewaterhouseCoopers. (2002). *Technology Forecast: 2002 – 2004, Volume 2: Emerging patterns of internet computing*, p. 127. Menlo Park, CA: Author.

[8] *The Economist*, Bespoke ships for the common man, 12 December, 2002.

[9] Parnell, K. (2002). *Could automotive processor obsolescence be history?* San Jose, CA: Xilinx. Available: http://www.xilinx.com/publications/whitepapers/index.htm Accessed: 20 April, 2003.

[10] DaimlerChrysler. (2002). Innovation at lightning speed – Flash technology in production and service. *High Tech Report*, *2*, p. 67-69. Stuttgart, Germany: Author. Available: http://www.daimlerchrysler.com/index_e.htm?/research/htr2002-2/htr2002-2_flash_e.htm Accessed: 20 April, 2003.

[11] Altera. (2002). *FPGAs provide reconfigurable DSP solutions*. San Jose, CA: Author. Available: http://www.altera.com/literature/wp/wp_dsp_fpga.pdf Accessed: 20 April, 2003.

[12] Keeling, S. (2002). NI extends LabVIEW to FPGAs. *ElectronicNews.com.au*, 2 September, 2002. Available: http://www.dialelectronics.com.au/articles/4e/0c01094e.asp Accessed:20 April, 2003.