Driving Flexibility into Automotive Electronics Design

With the dramatic increase in development costs for state-of-the-art process technologies, such as next-generation automotive electronic systems, specialization of traditional microcontrollers no longer makes business sense. This white paper discusses a process to develop an exact microcontroller for a specific application by implementing it into an Altera Cyclone IV FPGA for prototyping and volume production. Verification, software development, and field testing can be done immediately after design or even in parallel.

Introduction

Widely used in both automotive and consumer markets, microcontrollers provide a high level of system integration combined with a relatively low cost. However, there are hidden costs associated with these products. For example, if the part does not have just the right mix of features, it must be augmented with external logic, software, or other integrated devices. Furthermore, with rapidly changing end-market requirements, microcontrollers often become unavailable quickly. Many microcontrollers equipped with specialized features and a fixed number of dedicated interfaces do not fulfill market requirements after a short evaluation period. Consequently, system suppliers are forced to redesign their hardware and software, in some cases even having to change the processor core.

The ASSP-Based Microcontroller Dilemma

Traditional microcontroller manufacturers are faced with a dilemma that affects the entire market. A microcontroller is an application-specific product, so a new microcontroller with a different set of features is necessary for each application. In order to serve a broader market with one microcontroller core architecture, manufacturers offer microcontroller families with various members providing a mix of interfaces and functions. In many cases, however, this feature mix does not exactly fit specific customer requirements, so for large customer opportunities, a variant with a new set of interfaces and functions must be developed around a specific core architecture.

When microcontrollers were implemented in older technologies with relatively low manufacturing costs, this strategy was very successful. Unfortunately, with today's state-of-the-art process technologies used increasingly for higher levels of system integration, the development of new microcontroller variants is a significant cost factor. As only a few customer opportunities offer very high volume, this means that it no longer makes good business sense to produce such specialized devices for the requirements of a single customer. As a result, new microcontroller variants are equipped with more and more features in order to attract entire markets as they migrate to standard products rather than application-specific ones. While these additional features make the microcontrollers very powerful, they also increase the product cost. It then becomes more difficult to serve cost-sensitive markets, such as the automotive and consumer industries. There is no solution to this dilemma without changing the root cause of the problem, the fixed implementation of functions in silicon.

Flexible Microcontroller Solution

One possible solution to this dilemma is the flexible implementation of functions in silicon available with FPGAs, such as Altera's Cyclone® IV FPGAs (described in Table 1). These devices offer a powerful, viable alternative to microcontrollers because they significantly reduce engineering development time and the cost of multiple silicon iterations. Unlike microcontrollers that may be missing required features, FPGAs can be programmed and reprogrammed as needed during the design process, enabling more rapid prototyping and fast time-to-market. They also can be upgraded in the field if requirements change—even after the devices are deployed in a product.

Table 1. Automotive Features of Cyclone IV FPGAs

Features	Cyclone IV	Cyclone IV GX
Auto grade offered	✔	Under development
Unlimited reprogrammable	✔	✔
Automotive interfaces	CAN, I^2C, etc.	CAN, I^2C, etc. PCI Express (included as a hard block inside the FPGA)

Graphics controller applications are an example of where FPGAs are typically preferred over traditional controllers in automotive systems. While low-cost FPGAs for isolated functions such as graphics are accepted in the automotive market, more complex functions may be too expensive in a programmable device because of the huge silicon overhead necessary for programmability.

RISC CPU

I/O expansion using FPGAs has always been possible. The addition of PCI Express interfaces in both Cyclone IV FPGAs and Altera® Nios® II embedded processors enables a low-cost, easy-to-use, high-performance interconnect between the devices. You can develop companion chip solutions based on Cyclone IV GX FPGAs for any processor architecture, including popular 32-bit embedded processors from ARM, Freescale, and, more notably, Intel.

The CPU used in this solution, the Nios II embedded processor, does not reside on an unchangeable piece of pre-specified silicon, as is usually the case. Instead, it is automatically generated, based on the specifications defined by the system architect with the aid of the available tools, and is loaded into the FPGA with the remainder of the logic required for the entire circuit. Thus the processor core can be parameterized using Altera's SOPC Builder tool—found in the Quartus® II design software—based on the requirements for the specific application, and can be implemented with the exact functionality and corresponding consumption of logic required.

The Nios II processor is built on a standard RISC architecture with separate address buses and data buses, each 32 bits wide. Both buses operate via separate caches and can be continued separately into the bus system. Ultimately, the system architect determines whether to use separate memory for code and data or keep both in shared memory. Many of the functional units that every processor contains are present in Nios II processors, but the settings determine their character. For instance, the hardware multiplier, the barrel shifter, and the hardware divider can be selected as options. The same is true for the instruction and data cache, which can be varied in size or completely excluded.

Other CPU IP cores include:

■ ARM® Cortex-M1—32-bit RISC
■ Freescale V1 ColdFire—32-bit RISC
■ 8-/16-bit—various

Implementing the Microcontroller in an FPGA

For most low- to high-end feature sets (Figure 1), a Cyclone IV FPGA can be used as the prototyping vehicle and for volume production. Using an Cyclone IV FPGA minimizes the development risk dramatically as it offers opportunities for comprehensive verification, firmware development, and field testing. The FPGA allows an engineer to run the device in-system to exercise it in a real-world situation, thereby identifying potential design flaws that may not have been detected during simulation.

Software development has become a larger part of the overall development cycle. With the extended time and resources necessary for software development, using a Cyclone IV FPGA can shorten the overall development cycle. It can also help uncover bugs, compatibility issues, and the need for new hardware functions to support functionality that cannot be properly addressed or implemented by software.

Having systems available for field testing assists in uncovering system or device flaws that were not discovered in the lab. In many cases, having a demonstration system is a necessary requirement for the salesperson to secure a customer pre-order. New features and functionalities may also be required that were not part of the original specification. Whether for previously undiscovered flaws or to add new features, Cyclone IV FPGAs can be modified quickly without large nonrecurring engineering costs or long manufacturing cycles.

Figure 1. Flexible Automotive Microcontroller Solutions
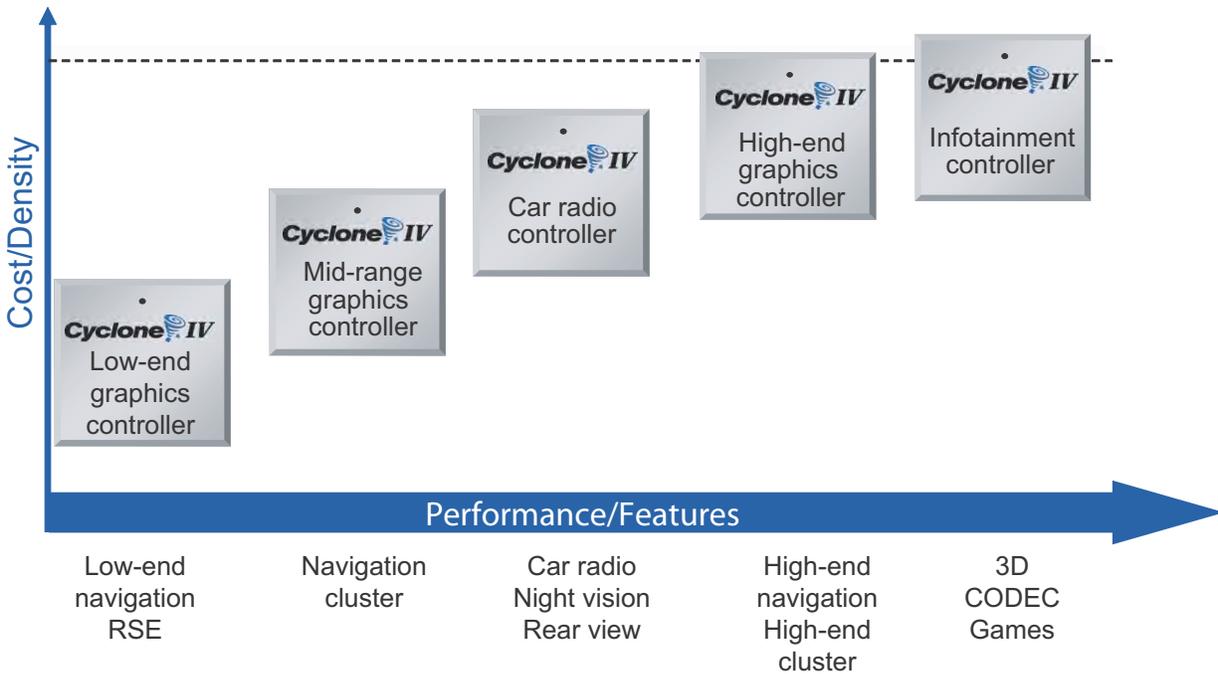
Conclusion

Next-generation automotive electronic systems need highly specialized, cost-optimized devices in order to meet the market requirements. Considering the dramatic increase in development costs for state-of-the-art process technologies, specialization of traditional microcontrollers no longer makes business sense. Neither do feature-rich devices targeted at broad-base markets, as they are often too expensive. Alternatively, the flexible microcontroller solution offers a process to develop the exact microcontroller for a specific application by implementing it into an Cyclone IV FPGA for prototyping and for volume production. Verification, software development, and field testing can be done immediately after design or even in parallel.

Further Information

- Altera's Automotive End Market:
  www.altera.com/end-markets/auto/aut-index.html
- Solution Sheet: *FPGA companion chip solutions from Altera*:
  www.altera.com/literature/po/ss-iocompanion.pdf
- Intel® Atom Industrial Reference Platform:
  www.altera.com/end-markets/industrial/io-hub/intel/ind-msc-platform.html
- ARM Cortex-M1 Processor:
  www.altera.com/products/ip/processors/32_16bit/m-arm-cortex-m1.html
- Freescale V1 ColdFire Processor:
  www.altera.com/products/ip/processors/32_16bit/m-fre-coldfire-v1.html

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