Embedded Processors on a Programmable Device

Altera® Excalibur™ embedded processor solutions give you the tools you need to integrate an entire system on a single programmable logic device (PLD). By combining programmable logic, memory, and a processor core on one device, the Excalibur solutions cut through the complexities of processor integration and deliver the ease-of-use, fast development time, and low non-recurring engineering (NRE) costs required for effective embedded systems development. The Excalibur solutions unite the advantages of programmable logic with the benefits of open-access processor core technology. Not only do the Excalibur products offer past ASIC users faster time-to-market, programmable flexibility, and low-risk technology, but they make low-cost, royalty-free access to advanced processor technology available to all embedded system designers. With the Excalibur technology, Altera introduces new system-on-a-programmable-chip (SOPC) solutions for your applications that require a fast, flexible development platform for system integration.

PLD Flexibility with the Power of Embedded Processors

The Excalibur solutions help speed development and shorten time-to-market for your embedded processor applications by offering both the ARM®-based hard core embedded processors and the Nios™ soft core embedded processors. Combined with programmable logic and memory, the Excalibur solutions give you all the programmable flexibility you need with single-chip integration.

The advanced features of the Excalibur solutions include:
- 200-MHz high-performance RISC embedded processor
- Support for a wide range of end RISC embedded processor applications
- Integrated hardware and software development workflow supported by:
  - Quartus® II design software
  - SOPC Builder system design tool
  - Industry-standard EDA tools
  - Real-time operating system (RTOS)
  - Complete software tool chain with compiler, debugger, linker, and assembler
- Pre-licensed, off-the-shelf devices with no royalties
- Optimized integration with Altera device architectures

The Excalibur solutions will expand as Altera introduces more advanced embedded processors with higher performance and enhanced functionality.

ARM-Based Excalibur Embedded Processor Solutions

Through partnership with ARM Ltd., Altera is able to offer the ARM922T™ RISC processor core embedded in the ARM-based Excalibur devices. This high-performance hard processor core, combined with the advanced features of the APEX™ 20KE device architecture, provides an outstanding embedded system development platform.

The ARM-based devices consist of an embedded processor stripe and programmable logic (shown in Figure 1). The stripe contains the processor with its associated caches, dual-port and single-port SRAM memories, peripherals, and debug modules. An industry-standard AMBA™ high-performance bus (AHB) allows the processor stripe to operate at up to 200 MHz. The stripe interfaces with the device’s programmable logic via dedicated bus bridges and dual-port RAM.

Advanced Memory Configuration

An integrated SDRAM controller supports single data rate (SDR) or double data rate (DDR) SDRAMs at up to 133 MHz or 266 MHz respectively, and up to 512 Mbytes of external SDRAM. The expansion bus interface (EBI) is compatible with industry-standard flash memory, SRAMs, and memory-mapped peripheral devices, directly supporting four devices (up to 32 Mbytes each).

Several standard peripherals are implemented in the stripe, including an interrupt controller, a universal asynchronous receiver/transmitter (UART) and a general-purpose timer. A watchdog timer is also provided for system checks.

High-Performance Architecture

The device logic is based on the APEX 20KE architecture and offers all of the APEX 20KE device’s powerful system-level features, including embedded system blocks (ESBs), support for a variety of I/O standards, and up to four phase-locked loops (PLLs). The logic elements (LEs) and ESBs in the logic portion of Excalibur devices can be used...
to implement custom logic or intellectual property (IP) functions from Altera’s extensive IP portfolio.

The embedded processor, SDRAM controller, and the device logic all have separate, independent clock domains with individual PLLs that feature the enhanced ClockLock™ and ClockBoost™ circuitry.

**Easy In-Field Upgrades**

Excalibur devices can be configured in several ways: the processor can configure the programmable logic from an external flash memory, or the processor can reprogram the configuration device (facilitating in-field upgrades). The embedded processor can reconfigure the system at any time.

**Integrated Hardware & Software Development**

The Excalibur solutions feature a fully integrated hardware and software development environment. The Quartus II software offers extended support for PLD development. Third-party compiler tools enable embedded software development, and the Altera MegaWizard® Plug-In Manager configures the embedded processor stripe and peripherals. Third-party software for the Excalibur devices includes the WindRiver Systems VxWorks AE RTOS, the ARM Development Lite Suite (ADS) for ARM-based Excalibur devices, and the Red Hat GNUPro software design suite.

**Nios Embedded Processors**

Nios is Altera’s Nios embedded processors, configurable RISC soft processors with 16-bit instruction sets and user-selectable 16- or 32-bit data paths, are the first RISC soft processors to be developed specifically for programmable logic. Delivered as part of a complete, easy-to-use development kit, the Nios embedded processors can be implemented in any of Altera’s ACEX™, FLEX®, APEX 20K, APEX II, Mercury™, or ARM-based Excalibur devices, and the Red Hat GNUPro software design suite.

**Flexible & Configurable Processor**

The Nios embedded processors include a library of standard peripherals that allow you to customize the system to suit your specific design requirements. Altera’s SOPC Builder system design tool provides an intuitive interface for choosing and configuring the desired set of peripherals. The SOPC Builder automatically generates the processor system, custom software library, and simulation test bench to further speed the development process and accelerate time-to-market.

A number of peripherals are available for the Nios embedded processor including:

- Timer/counter
- UART
- Parallel input/output (PIO)
- Serial peripheral interface (SPI)

**Figure 2. Nios Embedded Processor**

- Ethernet
- Direct memory access (DMA)
- On-chip debug
- Internal memory (RAM and ROM)
- External memory interfaces (SDRAM, SRAM, SSRAM, and flash)

You can also add your own peripherals to the Nios library. The added peripherals then appear as menu choices within the SOPC Builder design tool.

**Customizable Instruction Set**

Nios developers can accelerate time-critical software algorithms by adding custom instructions to the Nios instruction set. Custom instructions can reduce the time to perform complex, application-specific tasks to a single instruction, dramatically improving system performance. Custom instructions can access external memory and logic to further extend the design’s capability in applications such as digital signal processing (DSP) and packet header processing. The SOPC Builder design tool automatically adds user-designed custom instruction units to the Nios processor and generates C and assembly language macros for use by your software development team.

**Bus Architecture for High-Throughput Applications**

The Nios multi-master Avalon™ bus supports high-bandwidth applications, allowing you to virtually eliminate data flow bottlenecks within your system designs. The multi-master Avalon bus provides an infrastructure that allows simultaneous transactions by multiple bus masters, providing the gigabit throughput performance levels necessary for high-speed communications and data storage developers.

The simultaneous multi-master Avalon bus eliminates the need for processors to be involved in every data transaction. Instead, the Nios embedded processor can act as a traffic manager, directing data flow to optimize system throughput.
Each bus master resides on its own dedicated Avalon bus and can share peripherals with other masters through slave-side arbitration, eliminating bus-contention issues. You can select from several arbitration schemes, including priority-based, round-robin, or your own custom logic.

**Ideal for a Wide Range of Applications**

With the addition of IP functions, you can develop finite impulse response (FIR) filters, fast Fourier transforms (FFTs), and complete DSP systems. You can create industrial or automotive controllers by combining the Nios embedded processor with time processing units. By connecting media access controllers, error correction systems, or packet-processing modules, you can build complete network processing systems. Since the processors occupy only a small part of the device, several Nios embedded processors can fit onto one Altera PLD, giving you the design power you need for your most demanding applications. This multi-processor capability is especially useful in I/O-intensive applications such as networking and telecommunications.

**Obsolescence-Proof Processor**

The Nios embedded processor requires no license or royalty fees—you may create an unlimited number of Nios designs targeted for Altera devices. Since the Nios embedded processor supports the entire range of Altera look-up table (LUT) devices, your Nios designs can migrate to any LUT or mask-programmable logic device (MPLD) to take advantage of cost and performance benefits.

**Complete Development Kit**

The Excalibur development kit, featuring the Nios embedded processor (Figure 3), includes everything necessary to develop your own SOPC solution:

- Nios embedded processor and peripherals
- SOPC Builder design tool
- Quartus II Limited Edition development software
- GNUPro compiler, assembler, and debugger by Cygnus Software (a division of Red Hat Inc.)
- Development board with an APEX EP20K200E device
- Example reference designs

Additional accessory kits are available for the Nios development kit that provide support for Ethernet, PCI, and Linux development.

**Altera SOPC Solutions**

With the Excalibur high-performance embedded processors, Altera adds to its wide range of SOPC solutions. The advanced features, extensive tool support, and sophisticated debug environments of the Nios and ARM-based Excalibur products allow engineers to integrate an entire system on a single PLD with the ease-of-use and decreased time-to-market required for next-generation applications.

For full details of kits, parts, and availability, contact your local Altera sales representative, or visit the Altera web site at [http://www.altera.com](http://www.altera.com).