

## Features...



EXCALIBUR™

Preliminary Information



- Industry-standard ARM922T 32-bit RISC processor core operating at up to 166 MHz
  - Memory management unit (MMU) included for real-time operating system (RTOS) support
  - ARMv4T instruction set with Thumb® extensions
- Part of the Altera® Excilibur™ embedded processor solutions: system-on-a-programmable-chip (SOPC) architecture (see Figure 1 on page 4) builds upon features of the APEX™ 20KE family of PLDs, with up to 1,000,000 gates (see Table 1 on page 2)
- Advanced memory configuration support
  - Harvard cache architecture with separate 8-Kbyte instruction and 8-Kbyte data caches
  - Internal single-port SRAM up to 256 Kbytes
  - Internal dual-port SRAM up to 128 Kbytes
  - External SDRAM 133-MHz data rate (PC133) interface up to 512 Mbytes
  - External dual data rate (DDR) 266-MHz data rate (PC266) interface up to 256 Mbytes
  - External flash memory up to 32 Mbytes
- Expansion bus interface (EBI) is compatible with industry-standard flash memory, SRAMs, and peripheral devices
- Advanced bus architecture based on AMBA high performance bus (AHB)
- Embedded programmable on-chip peripherals
  - ETM9 embedded trace module to assist software debugging
  - Flexible interrupt controller
  - Universal asynchronous receiver/transmitter (UART)
  - General-purpose timer
  - Watchdog timer
- PLD configuration/reconfiguration possible via the embedded processor software
- Integrated hardware and software development environment
  - Extended Quartus™ development environment for Excilibur support
  - Altera MegaWizard® Plug-In Manager interface configures the embedded processor, PLD, bus connections, and peripherals
  - C/C++ compiler, source-level debugger, and RTOS support
- Advanced packaging options including SameFrame™ pin migration (see Tables 2 and 3 on page 3)
- 1.8-V and 2.5-V supply voltages

**Table 1. Current ARM-Based Embedded Processor Device Features** *Note (1)*

Feature	XA1	XA4	XA10
Maximum system gates	263,000	1,052,000	1,772,000
Typical gates (2)	100,000	400,000	1,000,000
LEs	4,160	16,640	38,400
ESBs	26	104	160
Maximum RAM bits	53,248	212,992	327,680
Maximum macrocells	416	1,664	2,560
Maximum user I/O pins	178	360	521
Single-port SRAM	32 Kbytes	128 Kbytes	256 Kbytes
Dual-port SRAM	16 Kbytes	64 Kbytes	128 Kbytes

**Note:**

(1) These features are preliminary. Contact Altera for up-to-date information.

(2) The embedded IEEE Std. 1149.1 Joint Test Action Group (JTAG) boundary-scan circuitry contributes up to 57,000 additional gates

## ... and More Features

- Fully configurable memory map
- Extensive embedded system debug facilities
  - SignalTap™ embedded logic analyzer
  - Software debug monitor
  - Real-time data/instruction processor trace
  - Background debug monitoring via the IEEE Std. 1149.1 (JTAG) interface
- Multiple and separate clock domains controlled by software-programmable phased-lock loops (PLLs) for embedded processor, SDRAM, and PLD
- PLL features include
  - ClockLock™ feature reducing clock delay and skew
  - ClockBoost™ feature providing clock multiplication
  - ClockShift™ programmable clock phase and delay shifting

**Table 2. ARM-Based Embedded Processor FineLine™ BGA & BGA Package Sizes** *Note (1)*

Feature	FineLine BGA			BGA	
	484 Pin	672 Pin	1,020 Pin	612 Pin	864 Pin
Pitch (mm)	1.00	1.00	1.00	1.27	1.27
Area (mm <sup>2</sup> )	529	729	1,089	1,225	2,025
Length × Width (mm × mm)	23 × 23	27 × 27	33 × 33	35 × 35	45 × 45

**Table 3. ARM-Based Embedded Processor FineLine BGA & BGA Package Options & PLD I/O Counts**  
*Notes (1), (2)*

Device	FineLine BGA			BGA	
	484 Pin	672 Pin	1,020 Pin	612 Pin	864 Pin
XA1	173 (3)	178 (3)		178	
XA4		275 (4)	360	215	360
XA10			521		365

**Notes to tables:**

- (1) Contact Altera for up-to-date information on package availability.
- (2) I/O counts include dedicated input and clock pins.
- (3) All FineLine BGA packages, except the 1,020-pin packages, are footprint-compatible via SameFrame pin-out. Therefore, designers can design a board to support a variety of devices, providing a flexible migration path across device densities and pin counts. Device migration is fully supported by Altera development tools.
- (4) This device uses a thermally enhanced package, which is taller than the regular package. Consult the *Altera Device Package Information Data Sheet* for detailed package size information.

# General Description

Part of the Altera Excalibur embedded processor PLD solutions, the family of ARM<sup>®</sup>-based embedded-processor devices combines an unrivalled degree of integration and programmability. The ARM-based devices are outstanding embedded system development platforms, providing embedded-processor and PLD performance that is leading edge, yet cost efficient.

The ARM-based family devices are offered in a variety of PLD device densities and memory sizes to fit a wide range of applications and requirements. Their high-performance, yet flexible, embedded architecture is ideal for compute-intensive and high data-bandwidth applications.

Figure 1 shows the structure of the ARM-based family. The embedded processor stripe contains the ARM processor core, peripherals, and memory subsystem. The amount of single- and dual-port memory varies as shown, and as listed in Table 1 on page 2. Figure 2 on page 5 shows the system architecture of the stripe, and its interfaces to the PLD portion of the devices. This architecture allows stripe and PLD to be optimized for performance, enabling maximum integration and system cost reductions.

Figure 1. ARM-Based Embedded Processor PLD Architecture

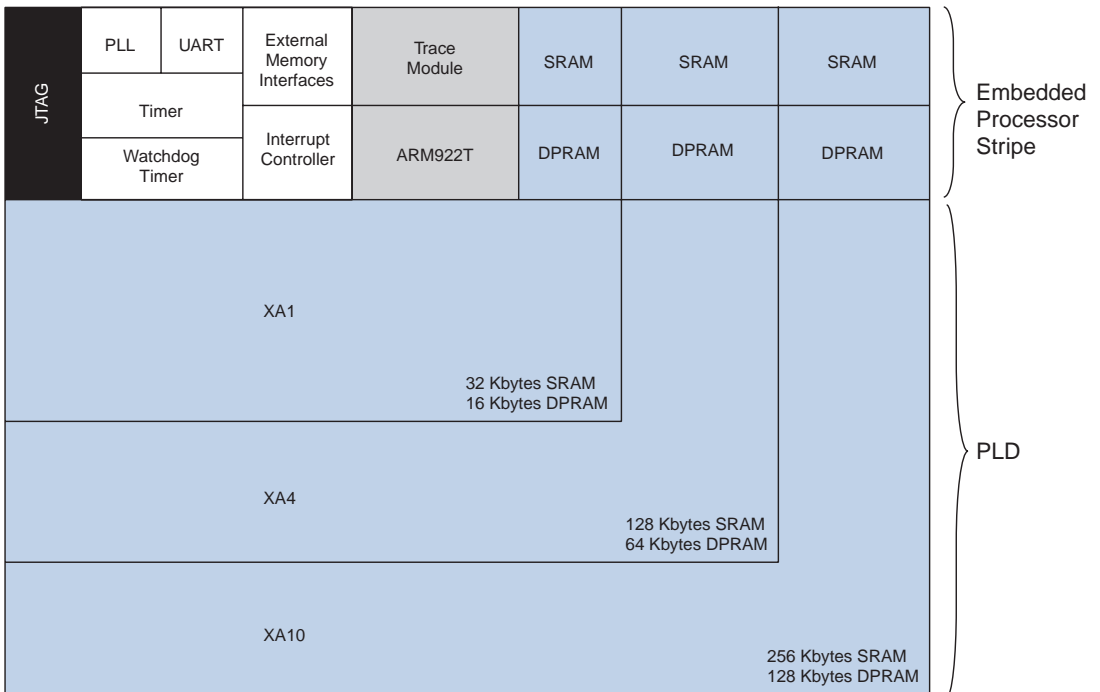
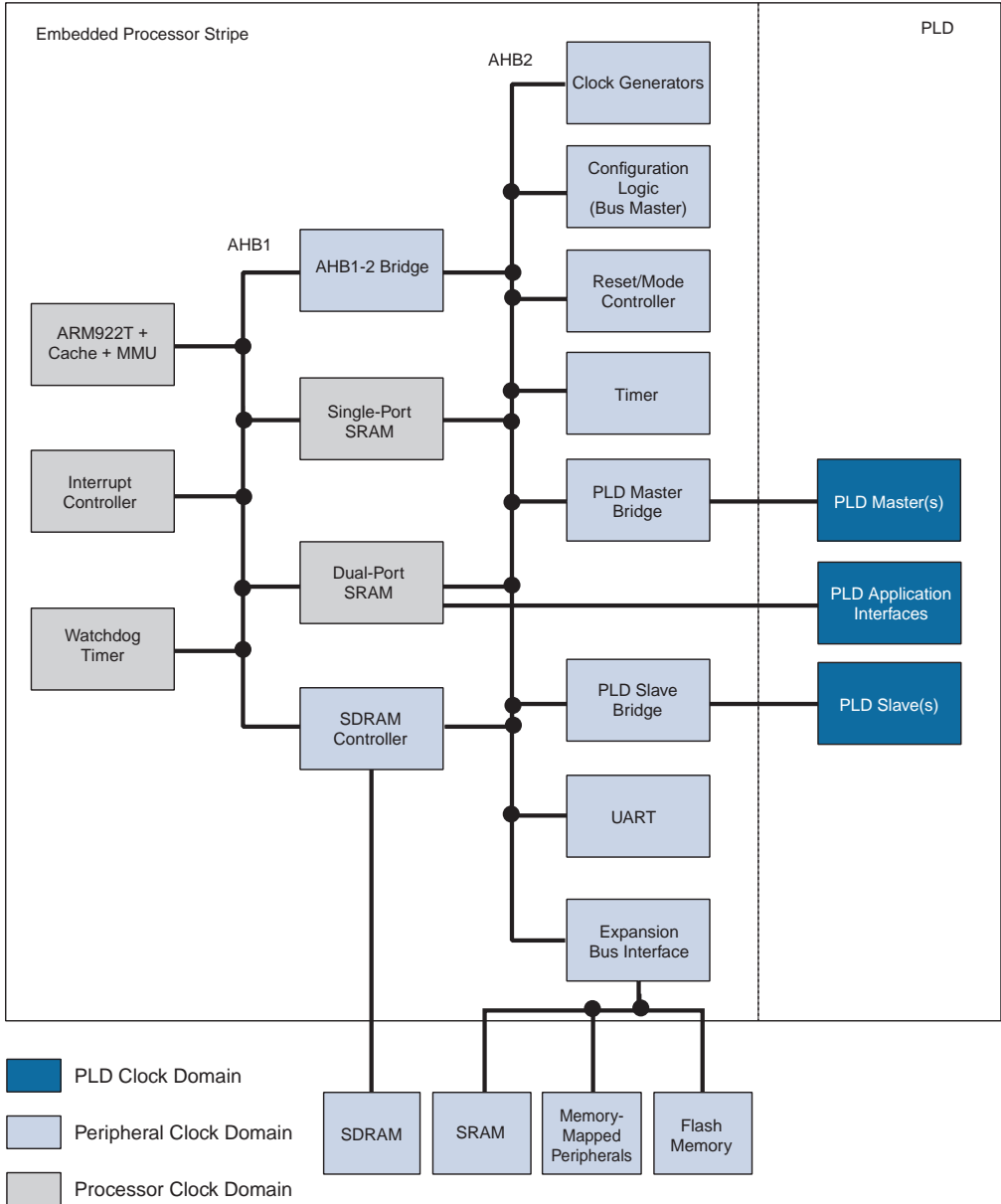


Figure 2. ARM-Based System Architecture



Two AMBA-compliant AHB buses ensure that ARM-based embedded processor activity is unaffected by peripheral and memory operation. Three bidirectional AHB bridges enable the peripherals and PLD to exchange data with the ARM-based embedded processor.

The performance of the ARM-based family is not compromised by the addition of the interfaces to or from the embedded logic, and is equivalent to an ASIC implementation of an ARM922T on a 0.18- $\mu$ m CMOS process. The ARMv4T instruction set is binary-compatible with many other ARM family members.

ARM-based embedded processor devices are supported by Altera's Quartus development system, a single, integrated package that offers HDL and schematic design entry, compilation and logic synthesis, full simulation and worst-case timing analysis, SignalTap logic analysis, and device configuration. The Quartus software runs on Windows-based PCs, Sun SPARCstations, and HP 9000 Series 700/800 workstations.

The Quartus software provides NativeLink™ interfaces to other industry-standard PC- and UNIX workstation-based EDA tools. For example, designers can invoke the Quartus software from within third-party design tools. Further, the Quartus software contains built-in optimized synthesis libraries; synthesis tools can use these libraries to optimize designs for ARM-based embedded processor devices. For example, the Synopsys design compiler library, supplied with the Quartus development system, includes DesignWare functions optimized for the ARM-based architecture.

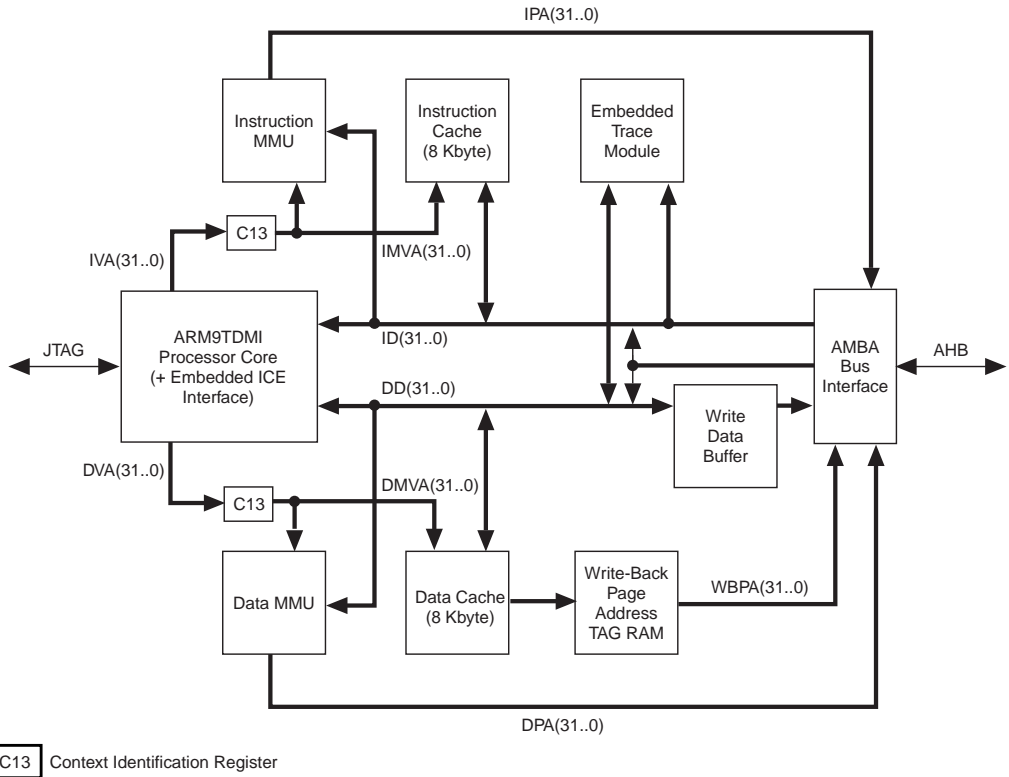
The ARM-based embedded processor PLDs have a system architecture (embedded processor bus structure, on-chip memory, and peripherals) that combines the advantages of ASIC integration with PLD flexibility.

## Functional Description

## ARM-Based Embedded Processor

Figure 3 shows the ARM-based embedded processor, the ARM922T.

Figure 3. ARM922T-Based Embedded Processor Internal Organization



The ARM922T is a member of the ARM9 Thumb family of processor cores, with Harvard architecture implemented using a five-stage pipeline. This implementation allows single clock-cycle instruction operation through simultaneous fetch, decode, execute, memory, and write stages. It supports both the 32-bit ARM and 16-bit Thumb instruction sets, allowing users to achieve a balance between high code density and performance.

Independent of PLD configuration, the embedded processor can:

- Access external boot memory
- Boot and run
- Program/reprogram the PLD without corruption of memory

- Run interactive debugging
- Detect errors and restart/reboot/reprogram the entire system as necessary
- Communicate with the external world and receive PLD updates
- Run a real-time operating system

## PLD Interfaces

The PLD can be configured via the configuration interface or the embedded processor. It can implement:

- Additional peripherals that connect to the embedded bus as masters, slaves, or both
- Coprocessors sharing the embedded logic as well as on-chip and off-chip memories
- Standard interface to on-chip dual-port RAM (allowing SRAM to function as a 'large' embedded system block (ESB))
- Additional embedded processor interrupt sources and controls

The master/slave/memory ports are synchronous to the PLD clock domain; however, the embedded processor domain and PLD domain can be asynchronous, to allow optimized clock frequencies for each domain. Resynchronization across the domains is handled by the AHB bridges in the embedded processor stripe.

Both the PLD master interface and the embedded processor-to-PLD slave interface are capable of supporting 32-bit data accesses to the whole 4-Gbyte address range (32-bit address bus).

The PLD can take full advantage of the extensive range of Altera intellectual property (IP) MegaCore® functions, reducing time-to-market and enabling complex SOPC designs.

## PLLs

The device PLLs build on the PLL features of the APEX 20KE devices.

Within the PLD, four PLLs are available. The PLLs can be configured in a manner similar to APEX 20KE PLLs.



In addition to the four APEX-style PLLs, ARM-based embedded processor PLDs have two PLLs that are frequency-programmable, both at configuration and via the system bus, to provide clocks for the:

- Embedded processor and associated modules
- Memory controller

The additional PLLs and associated routing support the following features:

- A common source for running additional PLLs
- Clock generation for the embedded processor and memory subsystem, allowing a synchronous mode
- LVTTTL 2.5-V and 3.3-V clock input
- PLL disabling, which allows the raw input clock to be routed as the main clock source

The memory controller PLL allows users to tune the frequency of the system clock to the speed of the external memory implemented in their systems.

## External Memory Controllers

The ARM-based embedded processor PLDs provide two embedded memory controllers that can be accessed by any of the bus masters: one for external DRAM, and a second for external flash memory or SRAM.

The DRAM memory controller supports the following commonly-available memory standards (SDRAM and DDR), without the addition of any glue logic:

- SDRAM 133-MHz data rates
- DDR 266-MHz data rates

A software-programmable PLL is used within the DRAM memory controller subsystem to supply the appropriate timings. Users can program the frequency to match the chosen memory components.

A second memory controller supports the interface to system ROM, allowing external flash memory access and reprogramming. In addition, static RAM and simple peripherals can be connected to this interface externally.

## Peripherals

The following peripherals are connected to the AHB:

- UART
- Timer
- Watchdog timer
- Interrupt controller

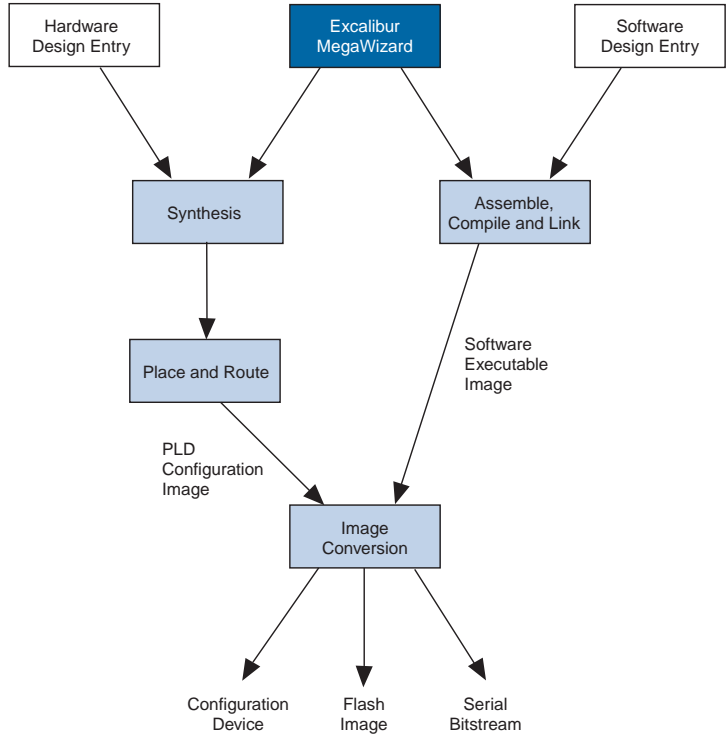
## Software Development Tools

The target software development tools offered by Altera are based on a combination of new tools, plus selected existing Altera and ARM developer suite (ADS) tools. The ARM-based embedded processor device is compatible with any available tools from ARM or third parties for the ARM922T.

The Altera development tools include:

- Fully-upgradable Altera-specific versions of the ARM developer suite
  - CodeWarrior software from MetroWerks
  - Graphical debugger
  - C/C++ compiler
  - Assembler
  - Linker
- Quartus support
  - C/C++ text editor
  - Software mode to build applications

Figure 4 shows the Quartus development tool flow.

**Figure 4. Quartus Development Tool Flow**

Altera supplies a variety of embedded software functions to support flash memory programming and PLD configuration.

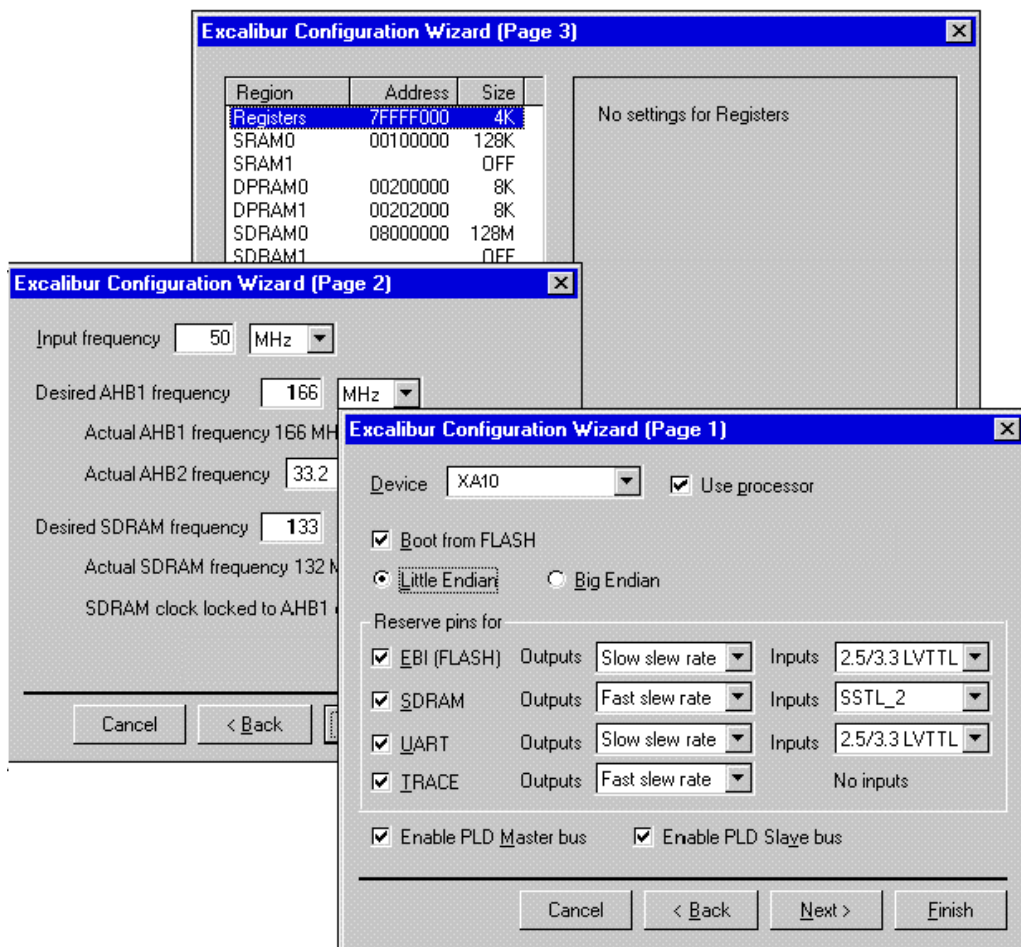
In addition, Altera provides device drivers for on-chip peripherals, and drivers to support PLD logic peripherals.

ARM-based embedded processor PLDs are configured at system power-up with data stored in a configuration device or flash memory. The same memory can store application software for the embedded processor. Additionally, the user can reconfigure the device in-circuit by using the on-chip processor, using configuration data stored anywhere in its memory system. The user can make real-time changes during system operation, which enables innovative reconfigurable computing applications.

## Configuration Wizard

The Altera Quartus development environment is enhanced by an Excalibur configuration wizard that allows pre-runtime setup of hardware and software functions. Figure 5 presents a typical set of screen shots from the configuration wizard, showing how users can, for example, select clock frequencies and booting options, and specify peripherals. This information is used to prepare a configuration bitstream that configures the PLD setup registers and on-chip SRAM as part of the configuration bitstream.

Figure 5. Excalibur Configuration Wizard



ds\_soc\_guide2

## Trace

A trace port provided on the ETM9 is compatible with the external trace analysis tools. This feature allows real-time visibility of embedded processor execution, and is tightly integrated with the source-level debugging tools.

## Simulation Model

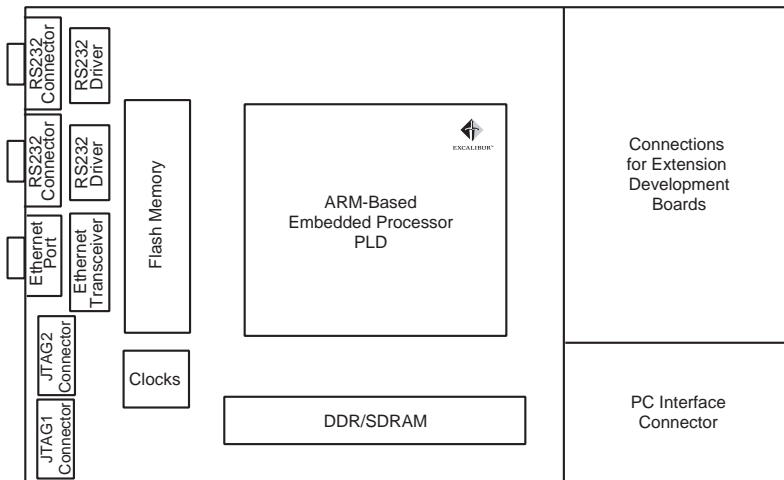
Initial simulation models of the ARM922 are compatible with the following simulators:

- Quartus simulator
- Verilog XL simulator
- ModelSim simulator
- Synopsys VSS simulator

## Evaluation Board

Altera offers separately an evaluation board compatible with the ARM-based embedded processor PLD, along with high-performance memories, debug interfaces, PCI bus connections, and capability for prototyping physical interfaces. Figure 6 illustrates the Altera evaluation board, showing the provision for board expansion.

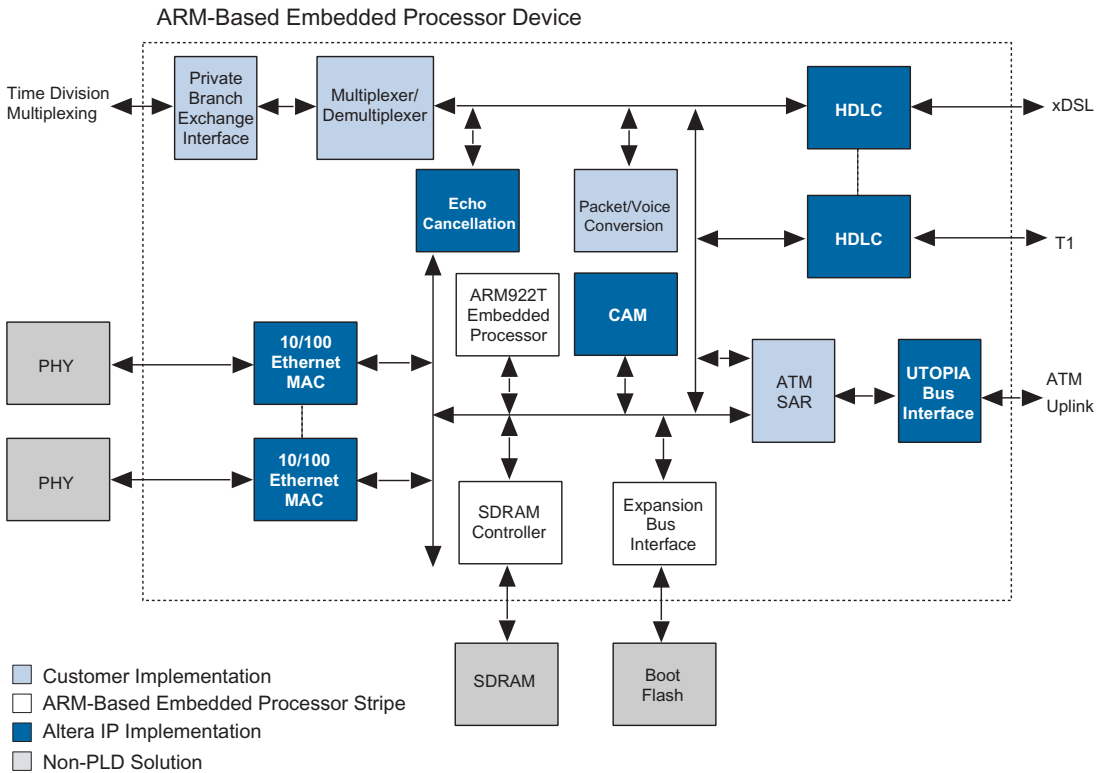
**Figure 6. ARM-Based Evaluation Board**



# Typical Application

Figure 7 shows how the ARM-based embedded processor and other elements can be integrated on a device. In this example, the ARM-based embedded processor device is configured for a voice-over packet gateway application. The elements of the embedded processor stripe, PLD modules, and off-chip peripherals are clearly identified.

Figure 7. ARM-Based Embedded Processor Device in a Voice-Over Packet Gateway Application



## Revision History

This version provides updated information, including:

- Revised maximum amount of external SDRAM supported
- Minor formatting and textual changes



*Notes:*



101 Innovation Drive  
San Jose, CA 95134  
(408) 544-7000  
<http://www.altera.com>  
**Applications Hotline:**  
(800) 800-EPLD  
**Customer Marketing:**  
(408) 544-7104  
**Literature Services:**  
[lit\\_req@altera.com](mailto:lit_req@altera.com)

Altera, APEX, ClockBoost, ClockLock, ClockShift, Excalibur, FineLine BGA, MegaCore, MegaWizard, NativeLink, Quartus, SameFrame, and SignalTap are trademarks and/or service marks of Altera Corporation in the United States and other countries. Altera acknowledges the trademarks of other organizations for their respective products or services mentioned in this document, including the following: ARM, Thumb and the ARM-Powered logo are registered trademarks of ARM Limited. Altera products are protected under numerous U.S. and foreign patents and pending applications, maskwork rights, and copyrights. Altera warrants performance of its semiconductor products to current specifications in accordance with Altera's standard warranty, but reserves the right to make changes to any products and services at any time without notice. Altera assumes no responsibility or liability arising out of the application or use of any information, product, or service described herein except as expressly agreed to in writing by Altera Corporation. Altera customers are advised to obtain the latest version of device specifications before relying on any published information and before placing orders for products or services.

Copyright © 2000 Altera Corporation. All rights reserved.



I.S. EN ISO 9001