



8. Description, Architecture, and Features

H51007-2.3

Introduction

HardCopy® APEX™ devices extend the flexibility of high-density FPGAs to a cost-effective, high-volume production solution. The migration process from an Altera® FPGA to a HardCopy APEX device offers seamless migration of a high-density system-on-a-programmable-chip (SOPC) design to a low-cost alternative device with minimal risk. Using HardCopy APEX devices, Altera's SOPC solutions can be leveraged from prototype to production, while reducing costs and speeding time-to-market.

A significant benefit of HardCopy devices is that customers do not need to be involved in the device migration process. Unlike application-specific integrated circuit (ASIC) development, the HardCopy design flow does not require generation of test benches, test vectors, or timing and functional simulation. The HardCopy migration process only requires the Quartus® II software-generated output files from a fully functional APEX 20KE or APEX 20KC device. Altera performs the migration and delivers functional prototypes in as few as seven weeks.

A risk-free alternative to ASICs, HardCopy APEX devices are customizable, full-featured devices created by Altera's proprietary design migration methodology. They are based on Altera's industry-leading high-density device architecture and use an area-efficient sea-of-logic-elements (SOLE) core.

HardCopy APEX devices retain all the same features as the APEX 20KE and APEX 20KC devices, which combine the strength of LUT-based and product-term-based devices in conjunction with the same embedded memory structures. All routing resources that were programmable in the APEX 20K device family are replaced by custom interconnect, resulting in a considerable die size reduction and subsequent cost saving.

The SRAM configuration cells of the original FPGA are replaced in HardCopy APEX devices by metal elements, which define the function of each logic element (LE), embedded memory, and I/O cell in the device. These resources are connected to each other using the same metallization layers. Once a HardCopy APEX device has been manufactured, the functionality of the device is fixed and no programming is possible. Altera performs the migration of the original FPGA design to an equivalent HardCopy APEX device using a proprietary design migration flow.

The migration of a FPGA to a HardCopy APEX device begins with a user design that has been implemented in an APEX 20KE or APEX 20KC device. [Table 8-1](#) shows the device equivalence for HardCopy and APEX 20KE or APEX 20KC devices.

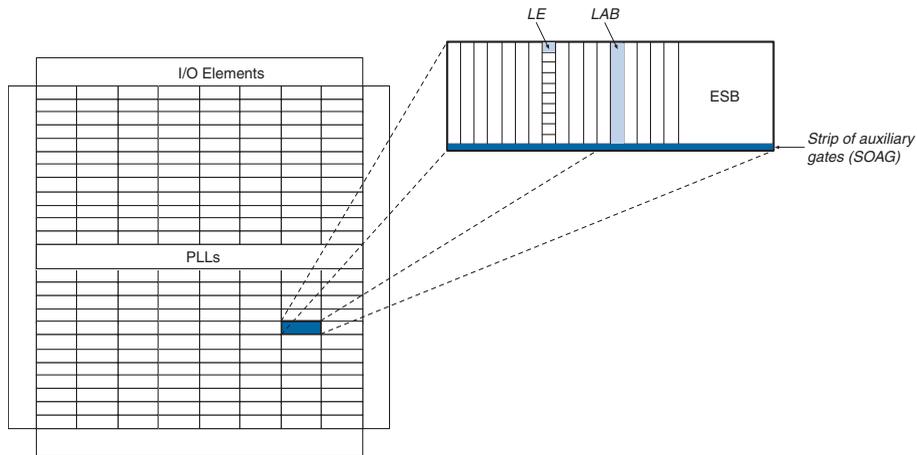
Table 8-1. HardCopy and APEX 20KE or APEX 20C Device Equivalence

HardCopy APEX Device	APEX 20KE Device	APEX 20KC Device
HC20K1500	EP20K1500E	EP20K1500C
HC20K1000	EP20K1000E	EP20K1000C
HC20K600	EP20K600E	EP20K600C
HC20K400	EP20K400E	EP20K400C



To ensure HardCopy device performance and functionality, the APEX 20K design must be completely debugged before committing the design to HardCopy device migration.

HardCopy APEX device implementation begins with extracting the Quartus II software-generated SRAM Object File (.sof) and converting its connectivity information into a structural Verilog HDL netlist. This netlist is then placed and routed in a similar fashion to a gate array. There are no dedicated routing channels. The router can exploit all available metal layers (up to four) and route over LE cells and other functional blocks. Altera's proprietary architecture and design methodology will guarantee virtually 100% routing of any APEX 20KE or APEX 20KC design compiled and fitted successfully using the Quartus II software. Place and route is timing-driven and will comply with the timing constraints of the original FPGA design as specified in the Quartus II software. [Figure 8-1](#) shows a diagram of the HardCopy APEX device architecture.

Figure 8–1. HardCopy APEX Device Architecture

The strip of auxiliary gates (SOAG) is an Altera proprietary feature designed into the HardCopy APEX device and is used during the HardCopy device implementation process. The SOAG structures can be configured into several different types of functions through the use of metallization. For example, high fanout signals require adequate buffering, so buffers are built out of SOAG cells for this purpose.

HardCopy APEX devices include the same advanced features as the APEX 20KE and APEX 20KC devices, such as enhanced I/O standard support, content-addressable memory (CAM), additional global clocks, and enhanced ClockLock circuitry. [Table 8–2](#) lists the features included in HardCopy APEX devices.

Table 8–2. HardCopy APEX Device Features (Part 1 of 2)	
Feature	HardCopy Devices
MultiCore system integration	Full support
Hot-socketing support	Full support
32-/64-bit, 33-MHz PCI	Full compliance
32-/64-bit, 66-MHz PCI	Full compliance
MultiVolt I/O operation	1.8-V, 2.5-V, or 3.3-V V_{CCIO} V_{CCIO} selected bank by bank 5.0-V tolerant with use of external resistor

Table 8–2. HardCopy APEX Device Features (Part 2 of 2)

Feature	HardCopy Devices
ClockLock support	Clock delay reduction $m/(n \times v)$ clock multiplication Drive ClockLock output off-chip External clock feedback ClockShift circuitry LVDS support Up to four PLLs ClockShift, clock phase adjustment
Dedicated clock and input pins	Eight
I/O standard support	1.8-V, 2.5-V, 3.3-V, 5.0-V I/O 3.3-V PCI and PCI-X 3.3-V AGP CTT GTL+ LVCMOS LVTTTL True-LVDS and LVPECL data pins LVDS and LVPECL clock pins HSTL class I PCI-X SSTL-2 class I and II SSTL-3 class I and II
Memory support	CAM Dual-port RAM FIFO RAM ROM

All HardCopy APEX devices are tested using automatic test pattern generation (ATPG) vectors prior to shipment. For fully synchronous designs near 100%, fault coverage can be achieved through the built-in full-scan architecture. ATPG vectors allow the designer to focus on simulation and design verification.

Because the configuration of HardCopy APEX devices is built-in during manufacture, they cannot be configured in-system. However, if the APEX 20KE or APEX 20KC device configuration sequence must be emulated, the HardCopy APEX device has this capability.



All of the device features of APEX 20KE and APEX 20KC devices are available in HardCopy APEX devices. For a detailed description of these device features, refer to the *APEX 20K Programmable Logic Device Family Data Sheet* and the *APEX 20KC Programmable Logic Device Family Data Sheet*.

Differences Between HardCopy APEX and APEX 20K FPGAs

Several differences must be considered before a design is ready for implementation in HardCopy technology:

- HardCopy APEX devices are only customizable at the time they are manufactured. Make sure that the original APEX 20KE or APEX 20KC device has undergone thorough testing in the end-system before deciding to proceed with migration to a HardCopy APEX device, because no changes can be made to the HardCopy APEX device after it has been manufactured.
- ESBs that are configured as RAM or CAM will power-up un-initialized in the HardCopy APEX device. In the FPGA it is possible to configure, or “pre-load,” the ESB memory as part of the configuration sequence, then overwrite it when the device is in normal functional mode. This pre-loaded memory feature of the FPGA is not available in HardCopy devices. If a design contains RAM or CAM with assumed data values at power-up, then the HardCopy APEX device will not operate as expected. If a design uses this feature, it should be re-compiled without the memory pre-load. ESBs configured as ROM are fully supported.
- The JTAG boundary scan order in the HardCopy APEX device is different compared to the APEX 20K device. A HardCopy BSDL file that describes the re-ordered boundary scan chain should be used.



The BSDL files for HardCopy APEX devices are different from the corresponding APEX 20KE or APEX 20KC devices. Download the correct HardCopy BSDL file from Altera’s website at www.altera.com.

- The advanced 0.18- μ m aluminum metal process is used to support both APEX 20KE and APEX 20KC devices. The performance improvement achieved by the die size reduction and metal interconnect optimization more than offsets the need for copper in this case. Altera guarantees that a target HardCopy APEX device will provide the same or better performance as in the corresponding APEX 20KE or APEX 20KC device.

Power-up Mode and Configuration Emulation

Unlike their FPGA counterparts, HardCopy APEX devices do not need to be configured. However, to facilitate seamless migration, configuration can be emulated in these devices. There are three modes in which a

HardCopy APEX device can be prepared for operation after power up: instant on, instant on after 50 ms, and configuration emulation. Each mode is described below.

- In instant on mode, the HardCopy APEX device is available for use shortly after the device receives power. The on-chip power-on-reset (POR) circuit will set or reset all registers. The `CONF_DONE` output will be tri-stated once the power-on reset has elapsed. No configuration device or configuration input signals are necessary.
- In instant on after 50 ms mode, the HardCopy APEX device performs in a similar fashion to the Instant On mode, except that there is an additional delay of 50 ms (nominal), during which time the device is held in reset stage. The `CONF_DONE` output is pulled low during this time and then tri-stated after the 50 ms have elapsed. No configuration devices or configuration input signals are necessary for this option.
- In configuration emulation mode, the HardCopy APEX device undergoes an emulation of a full configuration sequence as if configured by an external processor or an EPC device. In this mode, the `CONF_DONE` signal is tri-stated after the correct number of clock cycles. This mode may be useful where there is some dependency on the configuration sequence (for example, multi-device configuration or processor initialization). In this mode, the device expects to see all configuration control and data input signals.

Speed Grades

Because HardCopy APEX devices are customized, no speed grading is performed. All HardCopy APEX devices will meet the timing requirements of the original FPGA of the fastest speed grade. Generally, HardCopy APEX devices will have a higher f_{MAX} than the corresponding FPGA, but the speed increase will vary on a design-by-design basis.

Quartus II-Generated Output Files

The HardCopy migration process requires several Quartus II software-generated files. These key output files are listed and explained below.

- The SRAM Object File (`.sof`) contains all of the necessary information needed to configure a FPGA
- The Compiler Report File (`.csf.rpt`) is parsed to extract useful information about the design
- The Verilog atom-based netlist file (`.vo`) is used to check the HardCopy netlist
- The pin out information file (`.pin`) contains user signal names and I/O configuration information

- The Delay Information File (.sdo) is used to check the original FPGA timing
- A completed HardCopy timing requirements file describes all necessary timing information on the design. A template of this text file is available for download from the Altera website at www.altera.com.

The migration process consists of several steps. First, a netlist is constructed from the SOF. Then, the netlist is checked to ensure that the built-in scan test structures will operate correctly. The netlist is then fed into a place-and-route engine, and the design interconnect is generated. Static timing analysis ensures that all timing constraints are met, and static functional verification techniques are employed to ensure correct device migration. After successfully completing these stages, physical verification of the device takes place, and the metal mask layers are taped out to fabricate HardCopy APEX devices.

Document Revision History

Table 8-3 shows the revision history for this chapter.

Date and Document Version	Changes Made	Summary of Changes
September 2008, v2.3	Updated chapter number and metadata.	—
June 2007, v2.2	Minor text edits.	—
December 2006 v2.1	Updated revision history.	—
March 2006	Formerly chapter 10; no content change.	—
January 2005 v2.0	Update device names and other minor textual changes	—
June 2003 v1.0	Initial release of Chapter 10, <i>Description, Architecture and Features</i> , in the HardCopy Device Handbook	—

