CAM Comparison: APEX 20KE vs. Virtex-E Devices

Technical Brief 61 **December 1999, ver. 1**

Altera Corporation
101 Innovation Drive
San Jose, CA 95134
(408) 544-7000
http://www.altera.com
https://websupport.altera.com

Introduction

Content-addressable memory (CAM) is a memory technology that searches for data by its content rather than its address. When compared to RAM, CAM significantly reduces search times because it can compare the input data with a list of pre-stored entries in a single clock cycle. CAM therefore accelerates applications that require fast searches of databases, lists, or patterns, including Ethernet address look-up, data compression, pattern recognition, cache tag detection, fast routing-table look-up, high-bandwidth address filtering, security firewalls, and encryption.

Altera® APEX™ 20KE devices are the only programmable logic devices (PLDs) to provide dedicated CAM circuitry. This embedded CAM offers significant performance enhancements and more efficient resource utilization than other types of CAM. Traditionally, engineers have added discrete CAM to their designs, which introduces off-chip, on-chip delays and takes up valuable board space. Now, by using APEX 20KE CAM, engineers can take advantage of the flexibility and simple design integration of APEX devices, while benefitting from the faster access time and increased board space offered by a single-chip solution. One APEX 20KE device can even accommodate some typical, large-sized Internet CAM applications, such as Layer-3 address caching for Internet Protocol version 4 (IPv4) switches. APEX 20KE CAM addresses designers' needs by offering a variety of CAM depths and widths, and configuration flexibility.

Altera Applications recently compared the APEX 20KE CAM solution with the Xilinx CAM emulation to test the features, performance, and area utilization of each implementation. This technical brief describes the experiment and discusses the benefits of APEX 20KE embedded CAM.

Experiment

Altera Applications tested the performance of Xilinx Virtex-E and Altera APEX 20KE devices when implementing the largest possible CAM. Although APEX 20KE devices could implement a CAM as wide as 32 × 5,120 or as deep as 5,120 × 32, Altera Applications was restricted to testing 256 × 48 CAM because it was the largest CAM size the XCV1000E device could implement. The XCV1000E device was the largest device readily supported in the current Xilinx software: Alliance version 2.1i SP2. Altera chose to test the smallest and fastest device from each family that could fit this CAM size. The 256 × 48 CAM fit easily into the 8,230 logic element (LE) EP20K200E-1 device. However, Xilinx's CAM implementation required a device three times larger, the 24,576 equivalent-LE XCV1000E-8 device, and used every CAM block available in this device.

Lab Setup

The CAM implemented in both devices was set up with a similar function; both CAM implementations used multiple match mode with encoded outputs and an address width of 256 words and a data width of 48 bits.

CAM was implemented in the EP20K200E-1 device using the MegaWizard™ Plug-In Manager in the Quartus™ version 1999.10 software; the Quartus software was then used for synthesis and place-and-route.

M-TB-061-01

Xilinx provides a macro to emulate CAM in Virtex-E devices. CAM was implemented in the XCV1000E-8 device using Xilinx reference designs. To build a 256 × 48 CAM block, a 16 × 8 CAM design was modified according to the instructions in Xilinx *Application Note XAPP 204 (Using Block SelectRAM+ for High-Performance Read/Write CAMs)*. The design was synthesized with the Synopsys FPGA Compiler II version 3.3 software and transferred to the Xilinx Alliance version 2.1i SP2 software for place-and-route.

Area Utilization Results

To implement 256 × 48 CAM, the Xilinx Alliance version 2.1i SP2 software required all 96 SelectRAM+ Blocks in the XCV1000E-8 device. The same CAM implemented in the EP20K200E device consumed only 32 of the 52 embedded system blocks (ESBs) available in the device. Table 1 shows the results of the experiment, with the ESBs and SelectRAM+ Blocks converted into RAM bits for easy comparison.

Table 1. Area Utilization Comparison

Feature	EP20K200E-1	XCV1000E-8
RAM Bits Used	65,536	393,216
LEs Used *(1)*	695	1,732
Unused RAM Bits	40,960	0

Note:
(1) One Virtex slice is equivalent to two APEX LEs.

The results show that APEX 20KE devices consume 80% fewer RAM bits than Virtex-E devices and have additional memory to spare when implementing CAM.

Performance Results

CAM is typically implemented in high-speed applications. For this reason, CAM performance is critical to a design's overall success. Table 2 shows that the APEX EP20K200E-1 device operated at more than three times the frequency of the Virtex XCV1000E-8 device with the same functional CAM implementation.

Table 2. CAM Performance

Feature	EP20K200E-1	XCV1000E-8
Operating Frequency	116.29 MHz	45.47 MHz

Functionality

You can implement APEX 20KE embedded CAM with a wide range of modes and options. With the Quartus software, designers can configure APEX 20KE devices to implement single match, multiple match, or fast multiple match CAM, with the contents encoded or unencoded. These modes enable designers to optimize CAM for area utilization or performance. Table 3 describes each mode.

Table 3. CAM Mode Descriptions

Mode	Description
Single Match	Use single match mode when the input pattern only matches one stored pattern. When a match is found, the match flag goes high, and the output address bus displays the matched addresses. When using this mode, the data width cannot exceed 32 bits. This mode provides higher performance than other modes for similar CAM implementations.
Multiple Match	Use multiple match mode when the input pattern matches more than one stored pattern. When an address is found, the address match flags corresponding to the matched outputs go high. Encoded addresses can be generated from the match flags using LEs. This mode requires two read cycles to find a matched output.
Fast Multiple Match	Fast multiple match mode functions the same way as the multiple match mode but requires only one clock cycle to find an output. The fast multiple match mode requires twice the number of ESBs as the multiple match mode because it uses only half the available memory in each ESB.

APEX 20KE devices also have the unique ability to implement ternary CAM—a CAM configuration that accepts don't care bits—while consuming only a limited number of LEs and no additional ESBs. Xilinx Virtex-E devices do not support ternary CAM.

Table 4 compares the different CAM implementations supported by each device family.

Table 4. Supported CAM Implementations

Implementation	APEX 20KE Embedded CAM	Virtex-E CAM
Single Match Mode	✓	
Multiple Match Mode	✓	✓
Fast Multiple Match Mode	✓	
Ternary CAM	✓	

CAM Sizes

The flexibility of APEX 20KE devices allows designers to implement CAM with a variety of address depths and data widths. For example, designers can implement CAM in APEX 20KE devices as wide as $32 \times 5{,}120$ and as deep as $5{,}120 \times 32$. The Virtex-E CAM restricts the data width to multiples of 8, up to a total of 160 bits, and restricts the address depth to 32, 64, 128, or 256 words. Table 5 compares the CAM sizes offered by both device families.

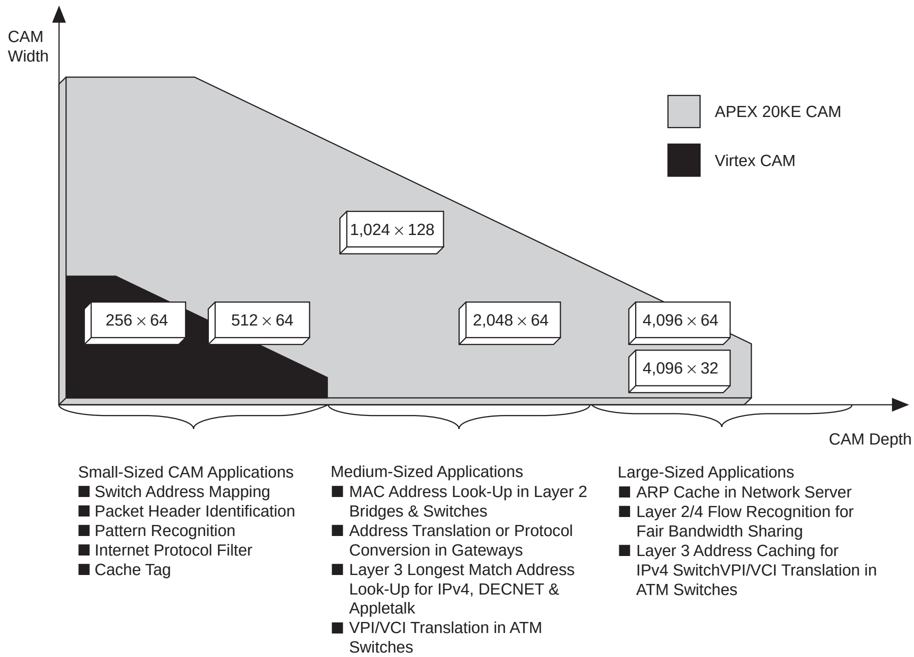
Table 5. CAM Size Comparison Note (1)

Feature	APEX 20KE CAM	Virtex-E CAM (2)
Dimension of Widest CAM	$32 \times 5{,}120$	128×160
Dimension of Deepest CAM	$5{,}120 \times 32$	$2{,}560 \times 8$

Notes:
(1) Table 5 shows a comparison between EP20K1000E and XCV1000E-8 devices.
(2) Source: Xilinx *Application Note XAPP 204 (Using Block SelectRAM+ for High-Performance Read/Write CAMs)*.

Figure 1 shows the various CAM applications that the APEX 20KE and Virtex-E devices can address. APEX 20KE devices can meet the needs of small- and medium-sized applications and many large-sized, high-speed CAM applications. Virtex-E CAM can address only small-sized, low-performance CAM applications. To implement medium- and large-sized CAM applications, designers must create external circuitry around the Virtex-E CAM.

Figure 1. CAM Application Sizes



Conclusion

APEX 20KE embedded CAM provides significant advantages in area utilization and performance. These advantages combined with the ability to implement a variety of CAM sizes and modes make APEX 20KE devices ideally suited for small-, medium-, and several large-sized applications.

ALTERA®

101 Innovation Drive
San Jose, CA 95134
(408) 544-7000
http://www.altera.com