CIRCUIT CELLAR ONLINE

THE MAGAZINE FOR COMPUTER APPLICATIONS

Circuit Cellar Online offers articles illustrating creative solutions and unique applications through complete projects, practical tutorials, and useful design techniques.

RESOURCE LINKS

A Guide to online information about:

Content-Addressable Memory (CAM)

by Bob Paddock

This month, I wanted to learn more about content-addressable memory (CAM). Look at a CAM as a memory that works backwards on a simplistic level. With most memories, you apply an address to get the data contents of that location. In a CAM you apply data and get an address in return. In reality, this address can be anything, not necessarily a location. In other words, you get back the data you are interested in, regardless of its location in the device, or an indication the data is not present in the device.

An example use for CAM is to decide if the traffic on a network is something you are interested in. The CAM monitors the appropriate bits in the network's address frame looking for a match. When the right data/address is applied to the CAM on its inputs, the CAM output will indicate if this traffic is of interest to us.

I have a couple different applications in mind for my CAMs. I want to see if it is practical to build an intrinsically safe TCP/IP router (Any one know of such a beasty?), and in a totally different area, I want to see if I can apply a CAM that has a hardware accelerator for doing Binary-Tree Searches to a speech recognition application.

"CAM Tutorial: An informative tutorial on what a CAM is and what it does."

by Music Semiconductor, one of the main suppliers of CAMs, is a good place to see what CAM is all about.

UTMC is a supplier of integrated circuits and circuit card assemblies for the aerospace and defense industry. Their UTCAM-Engine transforms conventional SSRAM or SDRAM into content addressable memory. Several interesting application notes in PDF format are available here, also.

Altera's APEX™ 20KE Integrated Content Addressable Memory devices offer integrated CAM to accelerate applications requiring fast searches of databases, lists, and patterns. CAM input data is compared against a list of stored entries in a single clock cycle, significantly reducing search time when compared to random-access memory (RAM). By eliminating on-chip/off-chip and board delays, the APEX integrated CAM provides greatly enhanced system performance over discrete CAM

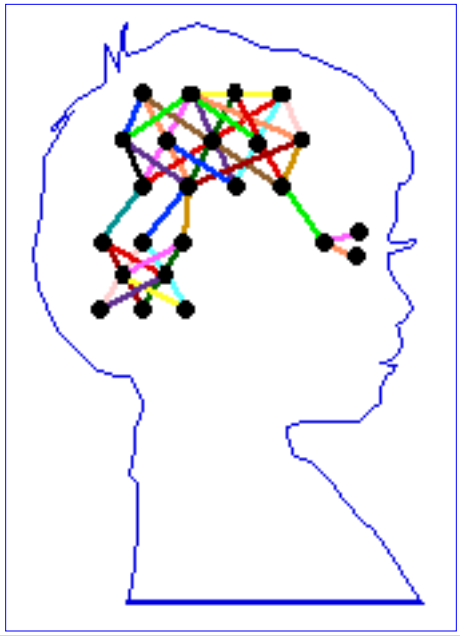
The heart of the APEX device architecture is the embedded system block (ESB). One APEX ESB can be configured to a 32-word × 32-bit CAM, and multiple ESBs can be cascaded together to implement wider and deeper CAMs.

On this web site there are application notes such as *AN 119 (Implementing High-Speed Searching Functions with APEX CAM) (PDF - 224 Kb)*, as well as others.

The book, *Introduction to Neural Networks* by Jeannette Lawrence, covers content addressable memory applications.

Although it is not related to the book directly, sample C code for a neural network-based CAM can be downloaded from the Simtel Archives.

ANNCAM.ZIP: Content-Addressable Memory Neural Network Simulator is a simple stable state content addressable memory neural network.



BrainMaker

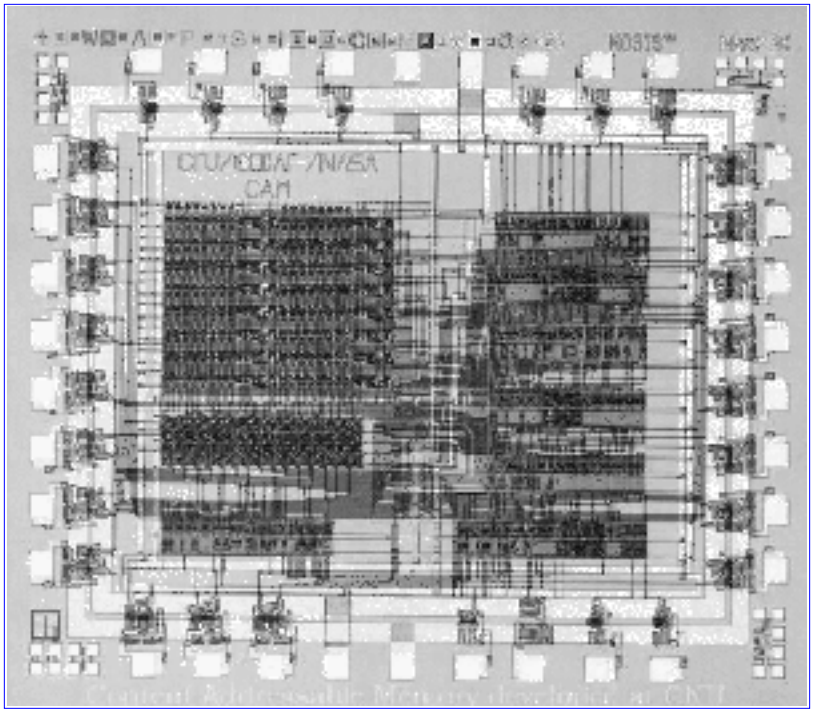
For more on the "WetWare" type of CAM, check out Psychology 258—*The Structure of Knowledge: A Connectionist Approach.*

CAM-Based Highly-Parallel Image Processing Hardware by Takeshi Ogura and Mamoru Nakanishi describes CAM-based hardware that serves as a highly parallel, compact, and real-time image-processing system. The novel concept of a highly-parallel integrated circuits and system (HiPIC), in which a large-capacity CAM tuned for parallel data processing, is a key element.

ChipCenter

Our own host, right here at ChipCenter, has table links and application information on CAMs. It's always nice to find things close to home.

CNU/CEBAF/NASA COLLABORATION
Content Addressable Memory (CAM)



A collaboration group has formed with Christopher Newport University (CNU) NASA and CEBAF National Laboratory to develop a custom CAM. The CAM will be 256 words × 32 bits. The CAM is being specifically developed for a particle tracking application at CEBAF and will be used in the Hall B triggering system. The CAM requires some special features not found in conventional CAMs. Its 32-bit word is divided into four bytes. Each byte can be independently matched. There is also a majority function that allows for word matches to be externally controlled and set to 1-, 2-, 3-, or 4-byte matches. This allows for partial (or fuzzy) word matches. The CAM is being designed with the Cadence tools in conjunction with the CMOSX 0.8 micron standard cell library. The prototypes have been fabricated through MOSIS.

The Electronic Systems Design Research Group Library Service has published a number of papers in different journals about CAMs, such as:

S.R. Jones, *100 Mbit/s Adaptive Data Compressor Design Using Selectively Shiftable Content-Addressable Memory*, Proc. IEE, Part G, Vol. 139, No. 4, August 1992, pp 498–502.

S.R. Jones, *Design, Selection and Implementation of a Content-Addressable Memory for a VLSI CMOS Chip Architecture*, Proc. IEE, Vol. 135, Pt. E, No. 3, May 1988, pp 165–172.

S.R. Jones, I.P. Jalowiecki, and R.M. Lea *On the Implementation of Content-Addressable Memories for VLSI CMOS Chip Architectures*, ESSCIRC '87, paper 4, session W 2.1.

S.R. Jones and R.M. Lea, *Content-Addressable Memories for WSI*, in Wafer-Scale Integration, (Eds G. Saucier and J. Trilhe), North-Holland, 1986, pp 115–125.

Fast-Chip claims to offer their PolicyEdge Product Family.

"PolicyEdge is a revolutionary packet classification network coprocessor product family adept at deep packet classification operations. Its on-chip memory provides ample space for sophisticated policy storage and allows the device to be a single chip solution for most applications. A database expansion port allows larger policy databases with additional Fast-Chip devices without incurring a performance penalty. With its highly flexible architecture, the PolicyEdge family is protocol independent making it ideal for edge routing products which act as interfaces or gateways for disparate networks."

Alas, when I went to the well-hidden section on datasheets, I was greeted with:

"A Fast-Chip representative will contact you shortly. Depending on the information you requested, a Non-Disclosure Agreement (NDA) may be necessary prior to receiving the detailed documentation."

If I sign it, I can't tell you about their product. If I don't sign, it I can't find out about their product. So, I still can't tell you about their product. Someone please wake me up when this starts to make sense—seems like a bad dream right now.

The CAME PXB 4360 from Infineon Technologies AG is a content addressable memory element, which searchs for a programmable 32-bit pattern, the corresponding programmable 14-bit pattern, or vice versa. Additionally, two search bits are provided to support the search for unused entries and to support the search for F4-OAM connections used in ATM.

Kawasaki LSI Online has developed a variety of application-specific standard products (ASSP). These products are targeted to the networking, personal computers and communications markets.

- Content Addressable Memory
  - Classification CAM
- Longest Match Engine(LME)
- Address Processor TM Family

Lara Networks doesn't seem to make CAMs, instead they provide "silicon solutions using its patent-pending Associative Processing Technology (APT)." I could not find any datasheets (just a form about datasheets) on their site to tell if these products might be useful to me. The site talked more about who was running the place and funding options. When I run in to this kind of site, I simply move on to another site with technical meat to it.

MOSAID seems to offer Ternary CAMs, which have the ablility to store 0, 1, and "don't care" values. It was not clear to me if they sell parts or intellectual property (IP). Either way, I could not locate CAM datasheets on their site.

Music Semiconductor seems like one of the main suppliers of CAMs. They have the most extensive list of application notes and application briefs of any site I visited while working on this Resource Page.

"CAM Tutorial: An informative tutorial on what a CAM is and what it does."

Motorola's content-addressable memories (CAMs) are implemented with standard 4-transistor SRAM cells. These CAMs are well suited for datacom applications, such as Virtual Path Identifier/Virtual Circuit Identifier (VPI/VCI) translation in ATM switches up to OC12 (622 Mbps) data rates and Media Access Control (MAC) address look up in Ethernet/Fast Ethernet bridges. CAMs are also well suited for fully associative disk drive cache and RAID applications.

Three application notes and datasheets for several of the Motorola CAMs are available at http://ebus.mot-sps.com/ProdCat/sg/0,1251,M98624,00.html.

(If anyone finds or has found a master index of all the Motorola's web sites, I'd like to know the URL.)

Some devices, such as National Semiconductor's *DP83953 (RIC2A) repeater interface controller with security features, internal drivers, and integrated filters*, contain 58 on-chip CAMs for storage of acceptable addresses.

The RIC2A is National Semiconductor's managed repeater solution designed to comply with IEEE 802.3 Repeater Specifications.

United States Patent for media access controller assigned to National Semiconductor is related:

> "A feature of the media access controller of the present invention is a content addressable memory architecture, whereby address filtering is provided for filtering physical, group and broadcast addresses on an Ethernet network."

NeoCore's NeoCAM was developed to give the you the best of all worlds—RAM prices, CAM speed, and associative memory flexibility.

An Introduction to NeoCAM by Chris Brandin explains the difference between CAMs and associative memories.

NetLogic Microsystems offers a complete range of products that enable wire-speed networking at data rates up to OC-768. Their product line targets the traditional bottleneck in networking—table management and searching.

They even offer "free" polo shirts, but alas, this is what I got when I filled in their survey:

> "Thank you for completing our survey.
>
> Our polo shirts are reserved for customers designing and building network
> and switch equipment. From the information provided it does not appear that
> Matric Limited would fit that profile."

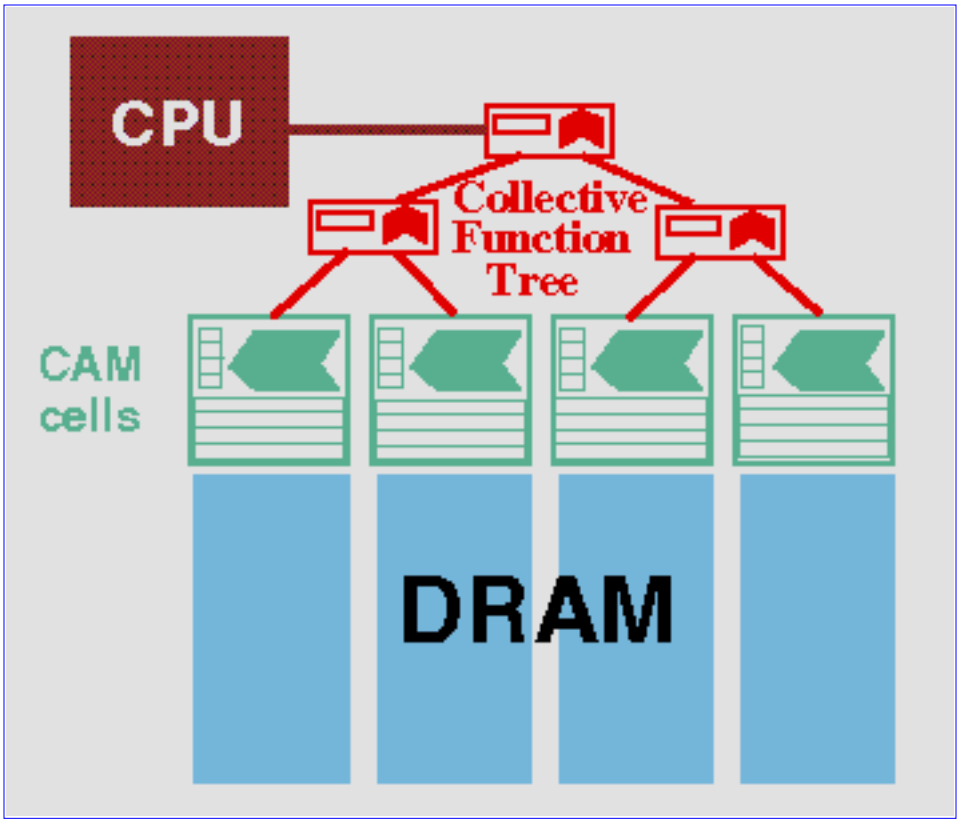
I've run into this in several places over the years. Even though industry equipment is the foundation upon which everything else in the product food chain is built, it lacks "coolness." Why is a router in a coal mine any different, besides the interracially safety requirements, than one in the office of an Internet Service Provider?

Jason Podaima did his thesis on *A Content Addressable FIFO for Shared Buffer ATM Switch Architectures.*

Quality Semiconductor offers their QS761480 1K × 64 and QS762470 2K × 64 CAMs.

- 16-bit I/O interface
- Pin compatible with the MUSIC MU9C1480/A and MU9C2480/A
- Memory array width can be configured as a mixture of RAM and CAM cell on 16-bit boundaries
- Priority encoder for highest-priority address match
- QCAMs are easily depth-expanded with no additional logic.

Another powerful feature is the instruction set, which allows flexible bit and word masking.



The Rutgers CAM2000 Memory Architecture uses the concepts of associative processing to overcome the shortcomings of conventional von Neumann machines in dealing with compute-bound applications involving massive amounts of data such as database mining. The architecture provides hardware support for data parallel, reduction, broadcast, and parallel prefix/suffix operations within a memory architecture that is DRAM compatible.

The Rutgers CAM architecture enables the use of many algorithms that would otherwise be infeasible for lack of processing power. An example is

correlation search in databases (database mining). This technique allows much more general queries.

SiberCore Technologies develops packet forwarding engine (PFE) solutions using CAM technology.

If you would like to add any information on this topic or request a specific topic to be covered, contact Bob Paddock.
