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DEPARTMENT: MICRO LAW

Review of Patents Issued to Computer Architecture Companies in 2021

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This two-part article takes a break from my series on the *Analysis of Historical Patenting Behavior and Patent Characteristics of Computer Architecture Companies* in order to analyze the patents that were issued to 18 computer architecture companies in 2021. Part III of the series will return in the July/August issue of *IEEE Micro*.

This two-part article first examines the number of total patents and the number of computer architecture patents that were issued to each company in 2021. Second, it compares the distribution of those patents across different patent classes. Third, it highlights one patent from each company that may be particularly notable.

I define a patent as a "computer architecture" patent if it was classified in the G06F, G06T, G09G, G11B, G11C, H03M, or H04L patent classes of the Cooperative Patent Classification System. Table 1 presents the title of each computer architecture patent class.

To improve readability, I will refer to companies with multiple entities generally by the parent company's name. More specifically, I refer to AMD+ATI as "AMD," Avago+Broadcom as "Broadcom," Dell+EMC+VMware as "Dell+EMC," Marvell+Cavium as "Marvell," NXP+Freescale as "NXP," Renesas+Dialog+IDT+Intersil as "Renesas," and Via+Cyrix as "Via."

NUMBER OF ISSUED PATENTS AND ISSUED COMPUTER ARCHITECTURE PATENTS

Table 2 presents the number of all patents and the number of computer architecture patents that were issued to each company in 2021. The right-most column in Table 2 presents the percentage of all patents that are computer architecture patents. To improve the comparison of different companies, the results in Table 2 are arranged in descending order of the total number of issued patents (second column).

The results for all issued patents in Table 2 show that the companies are roughly divided into four groups. In the first group are Samsung and IBM.[a] These two companies had over 8,600 issued patents in 2021, which is approximately three to four times more than the companies in the second group. Apple, Dell+EMC, Intel, Microsoft, Qualcomm, and Amazon are in the second group. Each of these companies had between 2,000 and 3,000 issued patents in 2021. In the third group are NXP, ARM, Renesas, AMD, Marvell, and NVIDIA. Each of these companies had between 200 and 500 issued patents. Finally, SiFive, Via, and MIPS are in the fourth category, with 12, 7, and 0 issued patents, respectively.

As I described in my article in the September/October 2021 issue of *IEEE Micro*, Apple, Microsoft, and Samsung had the highest number of issued design patents for applications filed between 1996 and 2020, approximately 10% of each companies' number of issued patents.[b] Amazon had the fourth highest number, which accounted for 2.8% of Amazon's issued patents. For 2021, 14.7% of Apple's issued patents were design patents, 5.8% for Samsung, 1.4% for Microsoft, and 3.8% for Amazon. Because these results are for only a single year, is it unclear whether they represent a new trend or whether it is just due to a small sample size.

The results in the fourth column show that for four companies—Dell+EMC, ARM, AMD, and SiFive—over 70% of their issued patents are computer architecture patents. To the extent that it is unexpected that Dell+EMC has the highest percentage of computer

[a]Some sources have IBM as the company with the most patents and Samsung as #2. See, e.g., https://harrityllp.com/patent300/. The difference between those lists and the results in Table 2 is that the results in Table 2 present the number of patents for all Samsung entities, e.g., Samsung Electronics, Samsung Display, etc., whereas the former includes Samsung Electronics only.

[b]While a utility patent protects how an article is used and works, design patents, by contrast, protect how an article looks, or its "ornamental appearance."

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TABLE 1. Title of each computer architecture patent class.

Class	Title
G06F	Electric digital data processing
G06Q	Data processing systems or methods, specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes; systems or methods specially adapted for administrative, commercial, financial, managerial, supervisory or forecasting purposes, not otherwise provided for
G06T	Image data processing or generation, in general
G09G	Arrangements or circuits for control of indicating devices using static means to present variable information
G11B	Information storage based on relative movement between record carrier and transducer
G11C	Static stores
H03M	Coding; decoding; code conversion in general
H04L	Transmission of digital information, e.g., telegraphic communication

architecture patents, two potential reasons could explain this result. First, 97.6% of Dell+EMC's computer architecture patents are classified under the G06F ("Electric digital data processing") or H04L ("Transmission of digital information, e.g., telegraphic communication") patent classes. This may indicate that these two categories include subject matter that is not typically considered to be within the scope of computer architecture. Second, Dell+EMC's patents are concentrated in a smaller number of patent classes compared to similarly situated companies, which could tend to inflate the percentage of computer architecture patents. More specifically, for the eight companies with the highest numbers of issued patents (i.e., Samsung, IBM, Apple, Dell+EMC, Intel, Microsoft, Qualcomm, and Amazon), Dell+EMC's patents are distributed into the smallest number of patent classes (54). By contrast, Samsung, IBM, Apple, Intel, and Amazon's patents are all distributed into over 100 patent classes, whereas Microsoft and Qualcomm's patents are distributed into 80 and 60 patent classes, respectively. As a point of comparison, NXP's 484 patents were distributed into 52 patent classes, whereas Dell+EMC's 2,760 patents were distributed into 54 patent classes.

TABLE 2. Number of all patents and computer architecture patents issued in 2021.

Company	All Patents	Comp Arch Patents	Comp Arch %
Samsung	9,685	2,797	28.9%
IBM	8,675	4,983	57.4%
Apple	2,979	1,125	37.8%
Dell+EMC+VMWare	2,760	2,447	88.7%
Intel	2,738	1,428	52.2%
Microsoft	2,449	1,639	66.9%
Qualcomm	2,147	726	33.8%
Amazon	2,019	1,074	53.2%
NXP+Freescale	484	150	31.0%
ARM	383	333	86.9%
Renesas+Dialog+ IDT+Intersil	354	93	26.3%
AMD+ATI	243	191	78.6%
Marvell+Cavium	226	143	63.3%
NVIDIA	206	125	60.7%
Avago+Broadcom	88	33	37.5%
SiFive	12	9	75.0%
Via+Cyrix	7	4	57.1%
MIPS	0	0	N/A

The fourth column also shows that between 50% and 70% of Microsoft, Marvell, NVIDIA, IBM, Via+Cyrix, Amazon, and Intel's patents are computer architecture patents. But given that Via had only seven issued patents in 2021, it is difficult to conclude that this is a representative percentage. For the remaining companies, 25%–40% of their issued patents were computer architecture patents.

Finally, as was the case for the analysis with respect to the total number of patents, because these results are for only a single year, is it unclear whether the results in the fourth column represent a trend or whether it is just due to a small sample size.

For almost all companies, the patent class with the largest number of patents was one of three patent classes: the G06F ("Electric digital data processing"), the H01L ("Semiconductor devices; electric solid state devices not otherwise provided for"), and H04L ("Transmission of digital information, e.g., telegraphic communication"). Both the G06F and H04L patent classes fall within my definition of a computer architecture patent class. The H01L patent class appears to be largely directed toward

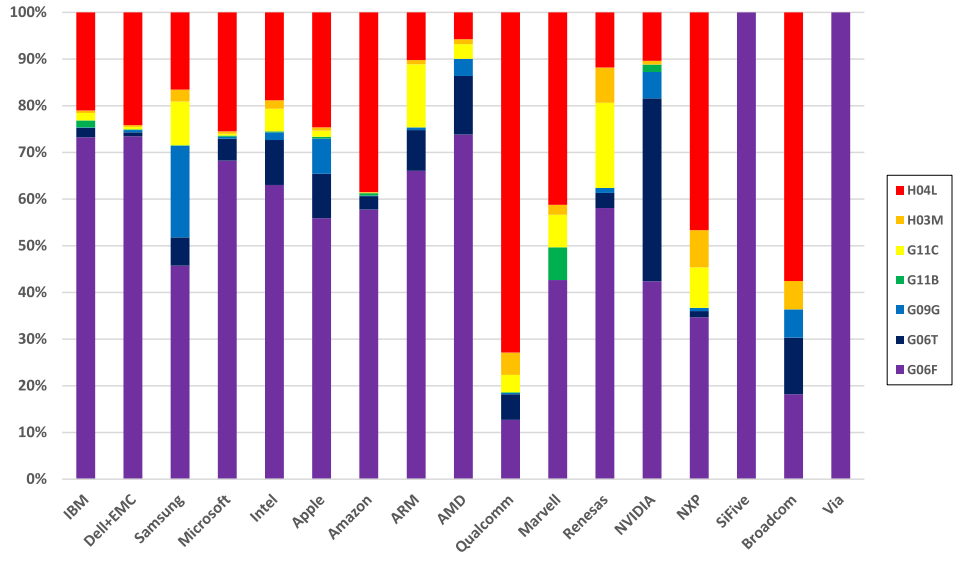

FIGURE 1. Distribution of patents in each computer architecture patent class as a percentage of the number of computer architecture patents for each company.

device-level semiconductors, including fabrication of those devices. The G06F patent class is the patent class with the largest number of patents for Amazon, AMD, Apple, ARM, Dell+EMC, IBM, Intel, Marvell, Microsoft, NVIDIA, SiFive, and Via. The H01L patent class is the largest class for Samsung and Renesas, whereas the H04L patent class is the largest for Broadcom and NXP. Qualcomm is the only company whose largest patent class is not any of these three patent classes; rather, Qualcomm's largest patent class is the H04W ("Wireless communication networks") patent class. This result is not surprising given that Qualcomm's business is primarily directed toward designing chips for wireless applications.

THE G06F PATENT CLASS IS THE PATENT CLASS WITH THE LARGEST NUMBER OF PATENTS FOR AMAZON, AMD, APPLE, ARM, DELL+EMC, IBM, INTEL, MARVELL, MICROSOFT, NVIDIA, SIFIVE, AND VIA. THE H01L PATENT CLASS IS THE LARGEST CLASS FOR SAMSUNG AND RENESAS, WHEREAS THE H04L PATENT CLASS IS THE LARGEST FOR BROADCOM AND NXP. QUALCOMM IS THE ONLY COMPANY WHOSE LARGEST PATENT CLASS IS NOT ANY OF THESE THREE PATENT CLASSES.

DISTRIBUTION OF PATENTS ACROSS PATENT CLASSES

Figure 1 depicts distribution of patents in each computer architecture patent class (listed in Table 1) as a percentage of the number of computer architecture patents for each company. Figure 1 does not include MIPS as MIPS did not have any issued patents in 2021.

Figure 1 shows that, with the exception of AMD, ARM, NVIDIA, and Renesas, the vast majority of computer architecture patents fall in either the G06F or H04L patent classes. For the vast majority of companies, the G06F and H04L patent classes account for at least 62.3% of all computer architecture patents (Samsung) to as high as 100% (SiFive and Via), with a median of 85.5%. For AMD and NVIDIA, the two largest patent classes were the G06F and G06T ("Image data processing or generation, in general") patent classes. This result makes sense as both companies design GPUs. The difference between the two companies is that the G06F and G06T patent classes account for 73.8% and 12.6%, respectively, of all of AMD's computer architecture patents, whereas the corresponding percentages for NVIDIA are more evenly split at 42.4% and 39.2%, respectively. For ARM and Renesas, the two largest patent classes were G06F and G11C ("static stores," which cover "devices or arrangements for storage of digital or analogue information").

To examine the similarity in the distribution of patents across all patent classes and computer architecture patent classes between companies, Figure 2 presents the output of a clustering analysis. To

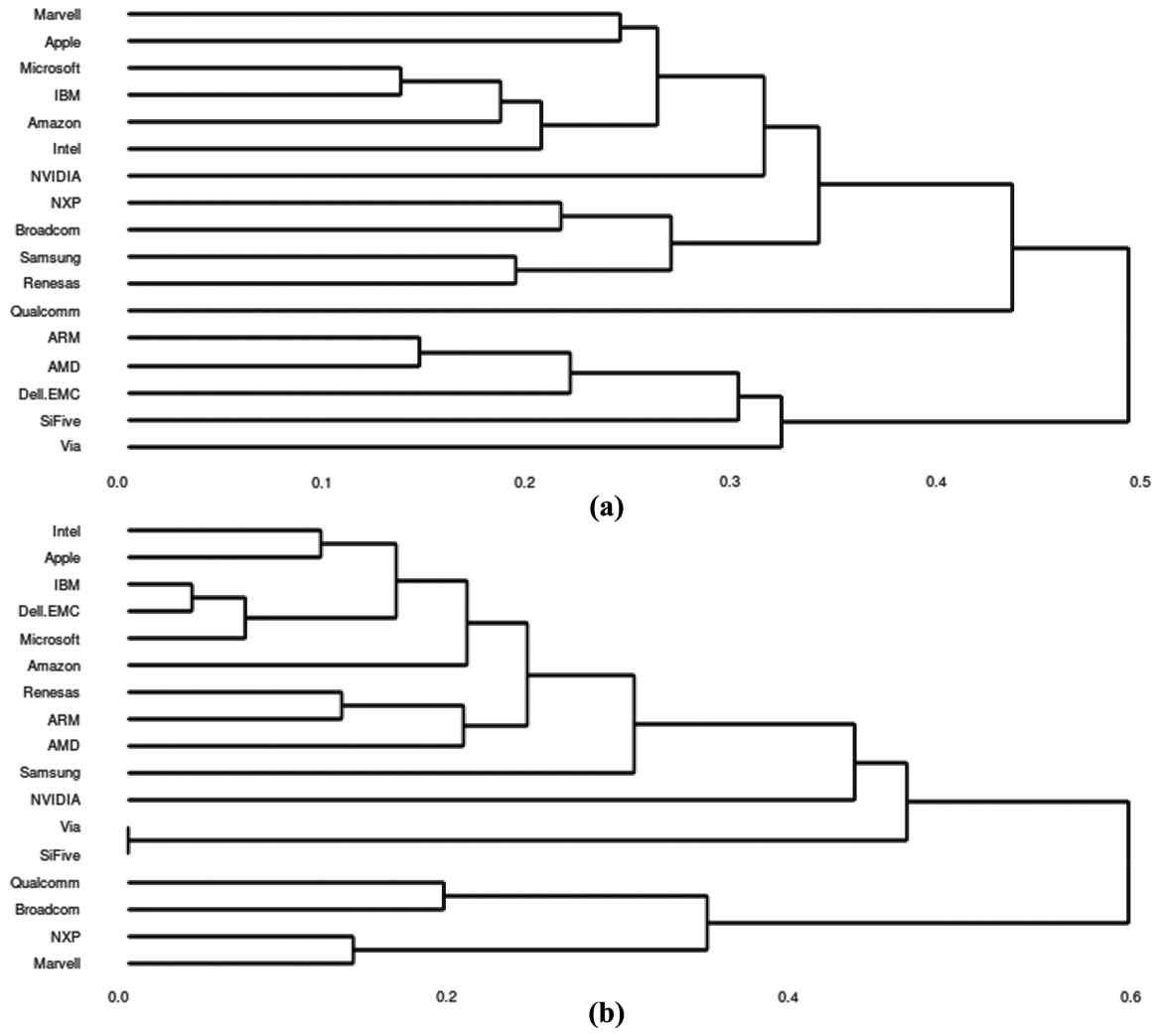

FIGURE 2. Dendrograms of the clustering analysis for all patent and computer architecture patents. (a) Clustering analysis for all patent classes (310 total). (b) Clustering analysis for computer architecture patent classes (7 total).

generate the results in Figure 2, I first "vectorized" the number of patents in each patent class [310 patent classes in Figure 2(a) and 7 patent classes in Figure 2 (b)] and then normalized the length of the vector to 1, in order to eliminate differences in the number of patents for each company. In the next step, I clustered the companies together based on their Euclidean distance, which is shown on the horizontal axis of Figure 2. Whenever two companies "join" together at a particular Euclidean distance, those two companies are in the same cluster for that Euclidean distance and greater. From a patent point-of-view, when two companies join together, this means that the distribution of patents for those two companies is similar. For example, in Figure 2(a), Microsoft and IBM join at a Euclidean distance of 0.13, which means that the distributions of patents for these two companies are more similar to each other than to any other companies. On the other hand, in Figure 2(a), Via is the last company to join with another company, which indicates that the distribution of Via's patents is very different than the distribution of patents for any other company. Each company or group of companies is successively clustered until there is only one cluster.

The number of horizontal lines from top to bottom at a given Euclidean distance represents the number of clusters. For example, in Figure 2(a), there are two horizonal lines at a Euclidean distance of 0.45, one for the ARM, AMD, Dell+EMC, SiFive, and Via cluster and the other for the remaining companies. The reason that ARM, AMD, Dell+EMC, SiFive, and Via are grouped together is because they have 1) patents in a relatively

small number of patent classes (e.g., 3, 4, and 18 patent classes for SiFive, Via, and ARM, respectively) and/or 2) a very high percentage of patents in one patent class (e.g., 73.8% and 100% for AMD and Via).

In Figure 2(b), at a Euclidean distance of approximately 0.45, the companies fall into three groups. The middle group (from top to bottom) consists of Via and SiFive. These two companies are grouped together because 100% of their computer architecture patents are in the G06F patent class. The bottom group consists of Qualcomm, Broadcom, NXP, and Marvell. These companies are grouped together because their largest computer architecture patent class is the H04L patent class. By contrast, the largest class for the companies in the top group is the G06F patent class.

NOTABLE PATENTS ISSUED IN 2021

The rest of this article presents a notable patent issued to each company from the G06F patent class. I limited the selection of patents to the G06F patent class for two reasons. First, the G06F patent class was the patent class with the largest number of patents for all but three companies (NXP, Broadcom, and Qualcomm). Second, the G06F patent class was the only patent class where all companies had a least one patent.

FIRST, THE G06F PATENT CLASS WAS THE PATENT CLASS WITH THE LARGEST NUMBER OF PATENTS FOR ALL BUT THREE COMPANIES (NXP, BROADCOM, AND QUALCOMM). SECOND, THE G06F PATENT CLASS WAS THE ONLY PATENT CLASS WHERE ALL COMPANIES HAD A LEAST ON PATENT.

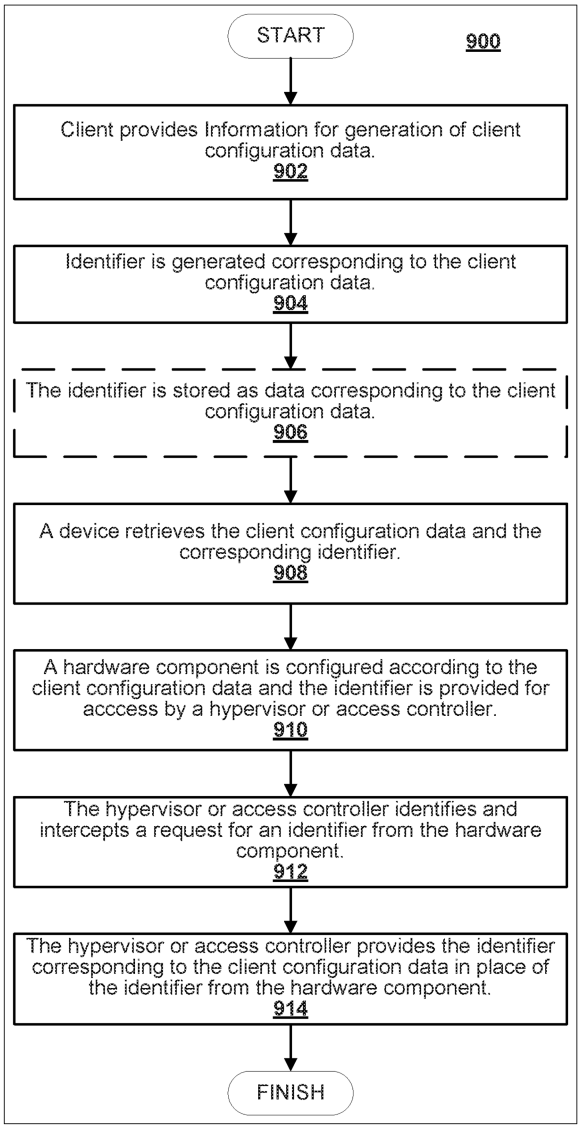

FIGURE 3. A representative figure from U.S. patent no. 10,963,268 issued to Amazon.

Because conventional wisdom and academic literature have indicated that valuable patents tend to come from larger patent families, the patents presented below are drawn from large patent families that had at least one issued patent in 2021. Furthermore, a large patent family tends to suggest that the company applying for that patent also believes that the patents are more valuable.

Assignee: Amazon
Number: 10,963,268
Filed: August 13, 2019
Issued: March 30, 2021
Title: Interception of identifier indicative of client configurable hardware logic and configuration data
Inventors: R. Johnson (Austin, TX), I. Atta (Vancouver, CA), A. Khan (Cedar Park, TX), N. Bshara (San Jose, CA), A. Liguori (Bainbridge Island, WA)
Abstract: Disclosed are techniques regarding aspects of implementing client configurable logic within a computer system. The computer system can be a cloud infrastructure. The techniques can include providing an identifier in response to configuring client configurable logic within the computer system.

Figure 3 "illustrates an example flowchart implementing certain features of the system" ('268 Patent).

Assignee: AMD+ATI
Number: 11,119,944

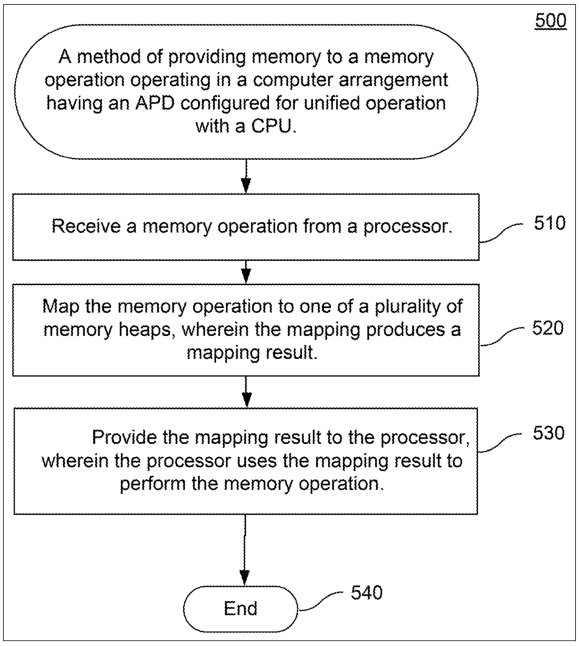

FIGURE 4. A representative figure from U.S. patent no. 11,119,944 issued to AMD.

Filed: June 17, 2019
Issued: September 14, 2021
Title: Memory pools in a memory model for a unified computing system
Inventors: A. Asaro (Markham, CA), K. Normoyle (Los Gatos, CA), M. Hummel (Franklin, MA)

Abstract: A method and system for allocating memory to a memory operation executed by a processor in a computer arrangement having a plurality of processors. The method includes receiving a memory operation from a processor that receives a memory operation from a processor that references an address in a shared memory, mapping the received memory operation to at least one of a plurality of virtual memory pools to produce a mapping result, and providing the mapping result to the processor.

Figure 4 is "a flowchart illustrating a method of providing memory to a memory operation operating in a computer arrangement having an accelerated processing device configured for unified operation with a CPU" ('944 Patent).

Assignee: Apple
Number: 10,963,037
Filed: December 21, 2018
Issued: March 30, 2021
Title: Conserving power by reducing voltage supplied to an instruction-processing portion of a processor

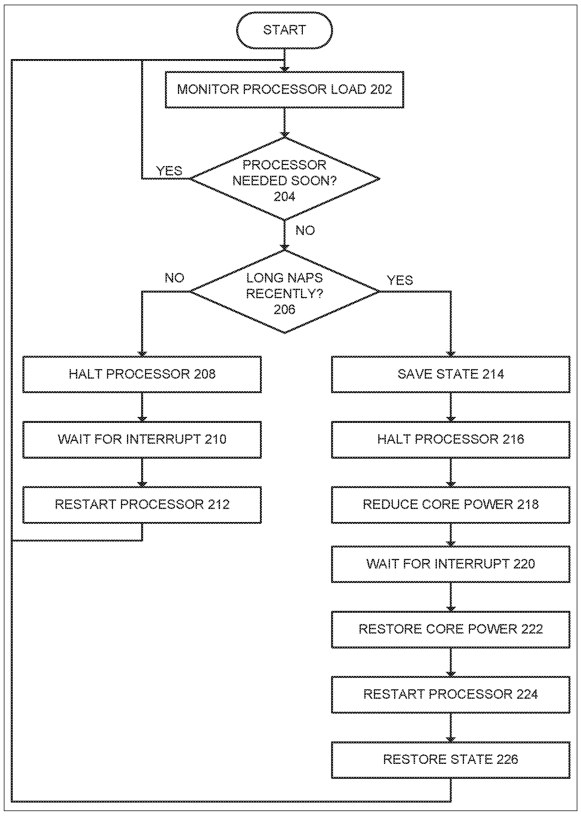

FIGURE 5. A representative figure from U.S. patent no. 10,963,037 issued to Apple.

Inventor: L. Youngs (Cupertino, CA)

Abstract: One embodiment of the present invention provides a system that facilitates reducing static power consumption of a processor. During operation, the system receives a signal indicating that instruction execution within the processor is to be temporarily halted. In response to this signal, the system halts an instruction-processing portion of the processor, and reduces the voltage supplied to the instruction-processing portion of the processor. Full voltage is maintained to a remaining portion of the processor, so that the remaining portion of the processor can continue to operate while the instruction-processing portion of the processor is in reduced power mode.

Figure 5 is "a flowchart illustrating the process of monitoring processor load and switching to power saving modes" ('037 Patent).

Assignee: ARM
Number: 11,176,012
Filed: March 18, 2020
Issued: November 16, 2021

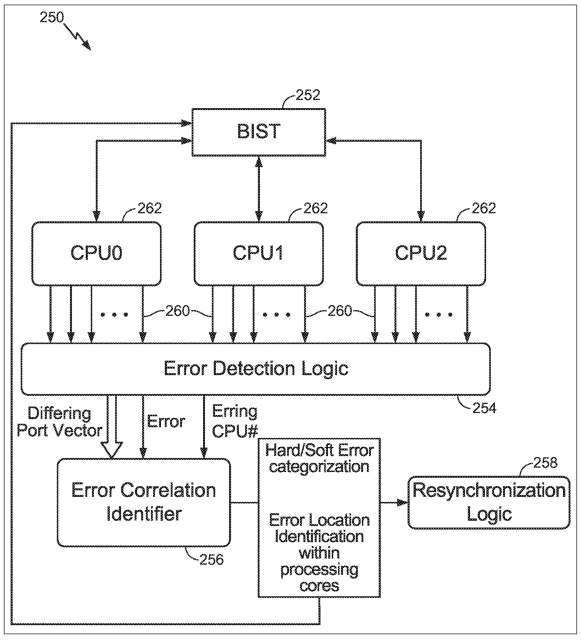

FIGURE 6. A representative figure from U.S. patent no. 11,176,012 issued to ARM.

Title: Device, system, and process for redundant processor error detection

Inventors: E. Ozer (Buckden, U.K.), X. Iturbe (Cambridge, U.K.), B. Venu (Cambridge, U.K.)

Abstract: Briefly, example methods, apparatuses, and/or articles of manufacture are disclosed that may be implemented, in whole or in part, to determine indicators of potential errors in a multiprocessing core lockstep computing device comprising a plurality of processing cores, based, at least in part, on observations of output signals generated by at least two processing cores of the plurality of processing cores. A built-in self-test procedure may then be based, at least in part, on the determining indicators.

Figure 6 depicts one example of the "lockstep processing systems" ('012 Patent).

Assignee: Avago+Broadcom

Number: RE48,845 (Reissue patent)

Filed: August 14, 2018

Issued: December 7, 2021

Title: Video decoding system supporting multiple standards

Inventors: A. MacInnis (Los Altos, CA), J. Alvarez (Sunnyvale, CA), S. Zhong (Santa Clara, CA), X. Xie (Freemont, CA), V. Hsiun (Palo Alto, CA)

Abstract: System and method for decoding digital video data. The decoding system employs hardware accelerators that assist a core processor in performing selected decoding tasks. The hardware accelerators are configurable to support a plurality of existing and future encoding/decoding formats. The accelerators are configurable to support substantially any existing or future encoding/decoding formats that fall into the general class of DCT-based, entropy decoded, block-

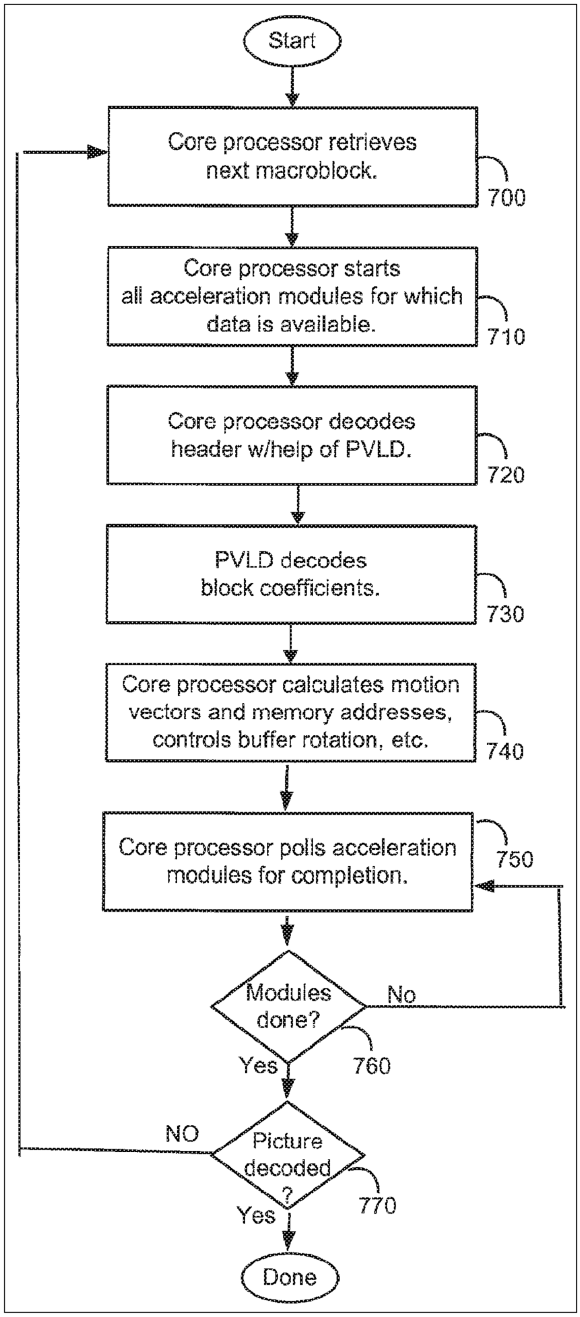

FIGURE 7. A representative figure from U.S. patent no. RE48,845 issued to Broadcom.

motion-compensated compression algorithms. The hardware accelerators illustratively comprise a programmable entropy decoder, an inverse quantization module, a[n] inverse discrete cosine transform module, a pixel filter, a motion compensation module, and a deblocking filter. The hardware accelerators function in a decoding pipeline wherein at any given stage in the pipeline, whereas a given function is being performed on a given macroblock; the next macroblock in the data stream is being worked on by the previous function in the pipeline.

Figure 7 is a "flowchart representing a macroblock decoding loop" ('845 Patent).

In my next article, I will present the notable patents for the remaining companies.

JOSHUA J. YI is a solo practitioner who serves as a court appointed technical advisor for the Honorable Alan D Albright, U.S. District Judge for the Western District of Texas, Waco Division, Waco, TX, USA. His research interests include microarchitecture and performance methodology. Yi received a Ph.D. degree in electrical engineering from the University of Minnesota, Minneapolis, MN, USA, and the J.D. degree from the University of Texas at Austin, Austin, TX, USA. Contact him at josh@joshuayipatentlaw.com.