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DEPARTMENT: MICRO LAW

Analysis of Historical Patenting Behavior and Patent Characteristics of Computer Architecture Companies—Part V: References

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In prior parts of this series, I analyzed the 1) number of all issued patents and issued computer architecture patents; 2) the prosecution time and effective patent term; 3) the number of claims, breakdown of independent and dependent claims, and effect that excess claim fees had on the numbers of total and independent claims; and 4) the type of claims (apparatus, method, or Beauregard), and effect that the Supreme Court's decision in *Alice v. CLS Bank* had on the number of independent and dependent method claims, for patents that were issued to 18 leading computer architecture companies and filed between 1996 and 2020. This article examines the 1) number of "backward" citations to previously issued/published U.S. patents and U.S. patent publications, foreign patents, and Other References and 2) the number of "forward" citations to a company's patent by another U.S. patent or U.S. patent publication.

Table 1 lists the number of patents that were filed between January 1, 1996, and December 31, 2020, and that were issued by March 31, 2022, for each of the 18 companies. The right-most column lists the number of patents that are classified as computer architecture patents.[a] During this timeframe, some companies merged (e.g., Dell merged with EMC) or made significant acquisitions (e.g., Avago acquired Broadcom). In order to ensure that the results accurately reflect the present form of combined companies, I included the merged or acquired companies if 1) the companies were computer architecture companies and/or 2) had a significant number of patents.

To improve readability, I will refer to companies with multiple entities generally by the parent company's name. More specifically, I will refer to AMD+ATI as "AMD," 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." In addition, I will refer to Avago+Broadcom as "Broadcom" as the latter may be the more well-known company and the company that is more relevant with respect to computer architecture.

"BACKWARDS" CITATIONS: NUMBER AND TYPE OF REFERENCES

On the first page of each U.S. patent is a section titled "References Cited." Because these references are citations to publicly available documents that were published or otherwise publicly available prior to the application date of the patent, they are often referred to as "backwards" citations.

The applicant or the examiner provides the references in the References Cited section. The applicant has a duty to disclose to the U.S. Patent and Trademark Office ("PTO") all prior art and other information "material to patentability."[b] An applicant's failure to fulfill this duty could result in the patent being unenforceable. In addition to this duty, by providing more of the relevant prior art to the examiner, the examiner is able to make a more informed decision as to whether the patent is different than the prior art,

[a] I classified a patent as a "computer architecture" patent if it was classified in the 345, 708, 709, 710, 711, 712, 713, or 714 patent classes of the U.S. Patent Classification System or G06F, G06T, G09G, G11B, G11C, H03M, or H04L patent classes of the Cooperative Patent Classification System. These are the same patent classes that I used in Parts I–III of this article series.

[b] 37 C.F.R. § 1.56

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TABLE 1. Number of all patents and computer architecture patents filed between January 1, 1996, and December 31, 2020, that issued by March 31, 2022.

Company	Issued Patents	Issued Computer Architecture Patents
Amazon	16,383	9,271
AMD+ATI	11,189	4,631
Apple	27,967	12,283
ARM	2,782	2,372
Avago+Broadcom	14,757	6,295
Dell+EMC+VMWare	21,427	14,098
IBM	133,927	82,812
Intel	45,679	24,643
Marvell+Cavium	8,626	5,193
Microsoft	47,561	32,144
MIPS	273	271
NVIDIA	3,957	3,139
NXP+Freescale	11,831	3,742
Qualcomm	29,242	10,155
Renesas+Dialog+IDT+Intersil	14,384	4,403
Samsung	136,045	37,174
SiFive	14	9
Via+Cyrix	1,981	1,325

which may increase the likelihood that the ensuing patent is valid over prior art.

The References Cited section divides references into three groups: 1) U.S. patent documents, which include both U.S. patents and U.S. patent publications, 2) Foreign patent documents, and 3) "Other publications." U.S. patent publications are applications that are published 18 months after the earliest priority date of the patent. The Other Publications section is a catch-all category that may include dictionaries, manuals, standards, legal briefs, academic papers, etc.

Figure 1(a) shows the average number of U.S. patent documents, foreign patent documents, and other publications cited in each patent for each of the 18 companies. Figure 1(a) depicts the results for all patents while Figure 1(b) shows the results for computer architecture patents only.

The results in Figure 1(a) show that the average number of U.S. patent documents ranges from 8.1 (SiFive) to 88.1 (Apple), with a median of 20.2. The average number of foreign patent documents ranges from 0.0 (SiFive) to 13.9 (Apple), with a median of 1.8. The average number of Other References ranges from 1.2 (Via) to 27.3 (Apple), with a median of 5.4. The results in Figure 1(b) shows that the distribution of references across U.S. patent documents, foreign patent documents, and Other References for computer architecture patents only is similar to the distribution of references for all issued patents shown in Figure 1(a).

U.S. PATENTS AND PUBLICATIONS ARE EASILY AND FREELY ACCESSIBLE. BY CONTRAST, FOREIGN PATENT DOCUMENTS MAY BE MORE DIFFICULT TO ACCESS, HARDER TO SEARCH FOR, AND MAY BE WRITTEN IN A DIFFERENT LANGUAGE.

Figure 1 shows that U.S. patent documents account for the majority of the cited references, more specifically, between 61.0% (SiFive) to 86.6% (Via), with a median of 71.0%. There are at least three reasons why these 18 companies—and, more generally, applicants from all fields—cite to U.S. patent documents more often, as compared to foreign documents or Other References. First, U.S. patents and publications are easily and freely accessible. By contrast, foreign patent documents may be more difficult to access, harder to search for, and may be written in a different language. Similarly, Other References, such as academic papers, may be difficult to access (e.g., behind a paywall) and/or search for, especially if the applicant or applicant's attorney does not know which journals and conferences may be contain the most relevant papers. Second, the date the patent is publicly available is more certain than when an academic paper was publicly available. Third, the applicant or applicant's attorney may have more trouble understanding academic papers as compared to patent documents. More specifically, the audience for academic papers is other researchers in that field, which tend to be professors and Ph.D. students. By contrast, patents are written for a person of ordinary skill in the art, which for computing engineering-related patents is typically a person with a bachelor's degree and two to four years of design—but not necessarily research—experience. Furthermore, academic papers—especially those in computer architecture journals and conferences—tend to heavily focus on results. As such, there may be less description and relatively few figures

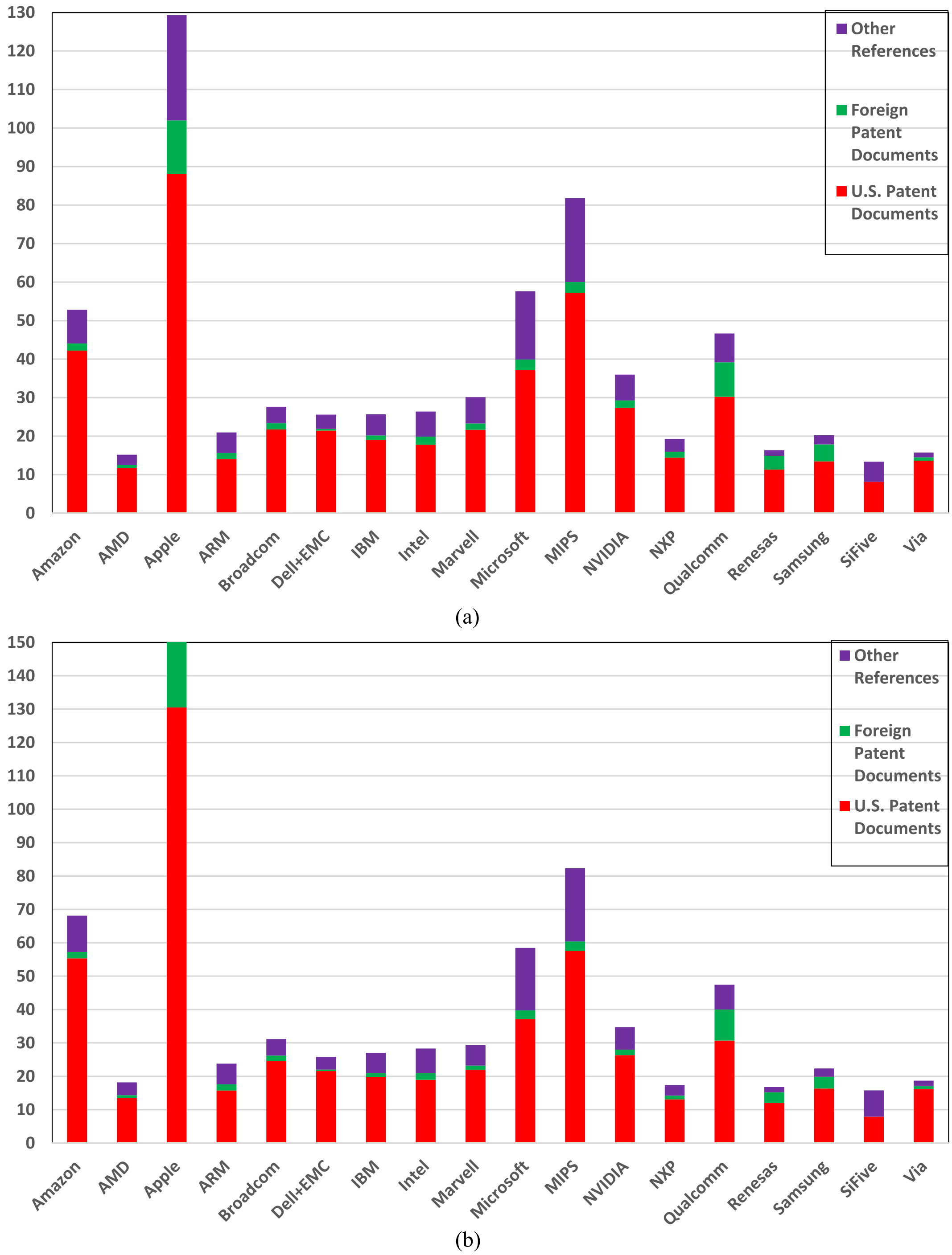

FIGURE 1. Average numbers of U.S. patent documents, foreign patent documents, and other references cited on patents for 18 computer architecture patents. (a) All issued patents. (b) Computer architecture patents only.

describing the proposed solution. Finally, academic papers are generally page-limited while patents and patent publications are not. As such, inventors have significantly more space to describe their inventions in a patent than researchers do to describe their proposed solutions in a conference paper. More description of an invention or proposed solution increases the chances that the applicant or applicant's attorney will understand the patent or paper, respectively, and determine whether it is relevant.

Comparing the results in Figure 1(a) with those in Figure 1(b) shows that these companies generally cite to more U.S. patent documents for their computer architecture patents as compared to all of their issued patents. More specifically, with the exception of NVIDIA, NXP, and SiFive, the computer architecture patents for all companies had 0.0 (Microsoft) to 13.1 (Amazon) more cited U.S. patent documents, as compared to all issued patents for each company. By contrast, the computer architecture patents for NVIDIA, NXP, and SiFive had 1.0, 1.3, and 0.3 fewer cited U.S. patent documents, respectively. What is particularly interesting is that NXP and SiFive have two of the lowest average number of cited U.S. patent documents, 14.4 and 8.1, respectively, for their issued patents, which is significantly lower than the median across all companies (20.2). Therefore, in contrast to almost all of the companies, which increased their numbers of cited U.S. patent documents for their computer architecture patents, NXP and SiFive's respective numbers *decreased*, and they started with two of the lowest numbers of such cited documents.

One reason why NXP and SiFive may cite to fewer U.S. patent documents for their computer architecture patents is that these companies believe that their computer architecture patents are more innovative as compared to all of their issued patents. In that case, there would be fewer relevant U.S. patent documents to cite to for their computer architecture patents, as compared to all of their issued patents. On other hand, NXP and SiFive may cite to fewer U.S. patent documents for their computer architecture patents because these two companies have a narrower view of what is relevant to their computer architecture patents, as compared to what is relevant for all of their issued patents.

With respect to foreign patent documents, eight companies cite to more foreign patent documents for their computer architecture patents while ten companies cite to fewer foreign patent documents. The companies in the former group include Amazon, AMD, Apple, Dell+EMC, MIPS, Qualcomm, SiFive, and Via. But, the difference in the number of citations—positive or negative—is generally relatively small. More specifically, with the exception of Apple and NXP, the difference in the number of citations for foreign patent documents for computer architecture patents as compared to all issued patents, i.e., computer architecture—all issued patents, ranges from -0.3 (Marvell) to 0.3 (Qualcomm). This relatively small range of difference is partially due to the relatively small number of citations to foreign patent documents and partially due to relatively small changes in the number of citations.

For Apple and NXP, the differences are larger, namely, 1.4 and −0.5, respectively. There does not appear to be any obvious reason why the differences between these two companies are larger.

With respect to Other References, five companies (ARM, Marvell, NXP, Qualcomm, and Samsung) cite to fewer Other References for their computer architecture patents as compared to all issued patents. For these companies, the difference ranges from −0.7 (Marvell) to −0.03 (ARM). For the other 13 companies, the difference ranges from 0.1 more citations (NVIDIA) to Other References for its computer architecture patents up to 9.1 more citations (Apple). There does not appear to be any obvious reason why ARM, Marvell, NXP, Qualcomm, and Samsung cite to fewer Other References for their computer architecture patents while the other thirteen companies cite to more Other References.

The results in Figure 1 also show that a small group of companies—Amazon, Apple, Microsoft, MIPS, NVIDIA, and Qualcomm—cite to significantly more total references as compared to the other 12 companies. More specifically, the average number of total citations for the first group of companies ranges from 36.0 (NVIDIA) to 129.3 (Apple), with a median of 55.2. By contrast, the average number of citations for the second group of companies ranges from 13.4 (SiFive) to 30.1 (Marvell), with a median of 20.6. In other words, the median number of cited references for the first group of companies is almost three times higher than the median number for the second group of companies. As described above, this could indicate the companies in the second group believe that their inventions are more innovative such that there are fewer relevant prior art references or they have a narrower view of what is relevant. On other hand, because companies in the first group cite to more references, the patents issued to these companies are more likely to be valid as the examiner reviewed more potential references that potentially could invalidate the patent, but still determined that the invention was different than the prior art.

Finally, comparing the average number of claims with the average number of references for all issued patents shows that there is a moderate positive correlation of 0.38 for all issued patents and 0.46 for computer architecture patents. But the correlation increases to 0.62 and 0.53, respectively, when Apple is excluded. Overall, one would expect that there would be more cited references when there are more claims because more claims mean more aspects of the invention are

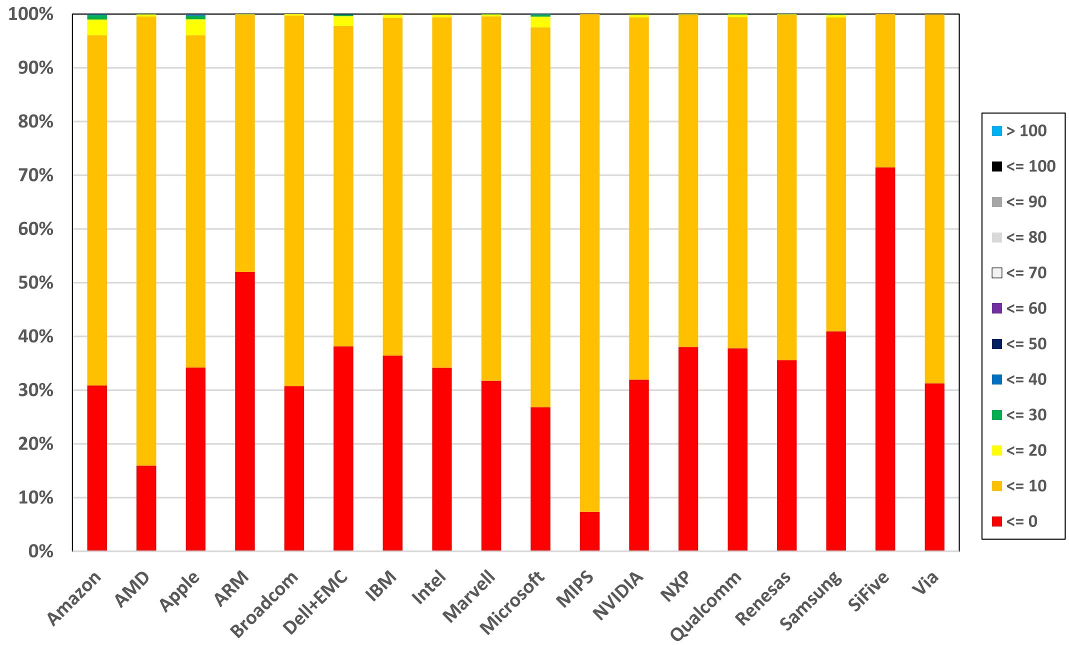

FIGURE 2. Histogram of the average number of forward citations per year.

covered by the claims, which concomitantly imply that more references may be relevant.

The reason that the correlation increases when Apple is excluded is because while Apple has a very high number of cited references—more than double the next closest company—its average number of claims for all issued patents is only slightly above the median. By contrast, Apple's average number of claims for its computer architecture patents is the fourth highest. Because there is more of a correlation between Apple's claims and cited references for its computer architecture patents as compared to all issued patents, this explains why the correlation for all companies did not increase as much for computer architecture patents when Apple was excluded, as compared to the correlation for all issued patents when Apple was excluded.

"FORWARD" CITATIONS: CITATIONS BY LATER-FILED ISSUED PATENTS

While the previous section analyzed the number of backward citations in each patent, this section analyzes the number of forward citations by later-filed patents. Forward citations are citations of a patent by another patent or patent publication that was (typically) filed after the first patent issued. And, in the same way that a large number of forward citations for an academic paper may indicate how innovative the paper is, a large forward citation count for a patent may indicate the value or how innovative the patent is.

Figure 2 is a histogram of the average number of forward citations for each patent per year for all issued patents. Analyzing the forward citations in terms of an annual average prevents older patents (that had more time to accumulate forward citations) from appearing to have more forward citations, and thus appearing to be more potentially valuable.

Figure 2 shows several interesting results. First, the percentage of patents that have zero forward citations ranges from 7.3% (MIPS) to 71.4% (SiFive), with a median of 34.2%. MIPS may have a very small percentage of patents with zero forward citations because it has very few issued patents to begin with (273). In other words, if even a small number of MIPS patents have forward citations, that will dramatically reduce the percentage of its patents that have zero forward citations. The percentage of SiFive patents that have zero forward citations is significantly higher than the company with the second highest percentage (ARM, 52.0%), which artificially increases the range of average forward citations across all companies. Second, the percentage of patents that have between 1 and 10 forward citations ranges from 28.6% (SiFive) to 92.7% (MIPS), with a median of 65.2%. Therefore, between the first two bins, 96.1% of all patents for all companies have 0–10 forward citations. Third, on the other hand, five companies have at least one patent that has over 100 citations, namely, Apple has eight, Samsung has three, and Dell+EMC, Microsoft, and Qualcomm each have one. Of these high forward citation count patents, three, one, and one for Apple, Dell+EMC, and Samsung, respectively are classified as computer architecture patents. The percentage of Apple's high forward citation count patents (37.5%) that are classified as computer architecture patents is similar to the percentage of Apple's patents are classified as computer architecture patents (43.9%).

Part VI in this series will analyze patent families for these companies for patents filed between January 1, 1996, and December 31, 2020.

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