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DEPARTMENT: MICRO LAW

Analysis of Historical Patenting Behavior and Patent Characteristics of Computer Architecture Companies—Part II: Prosecution Time and Effective Patent Term Length

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In Part I of this series that was published in the September/October 2021 issue of *IEEE Micro*, I analyzed the number and type of patents that were issued to 12 leading computer architecture companies for patents that were filed between 1996 and 2020. This article builds on that work by analyzing two specific characteristics of those patents, namely, it analyzes the prosecution time and the effective patent term. It also expands the scope of this series by adding six more computer architecture companies.

Table 1 lists the number of patents that were filed between January 1, 1996, and December 31, 2020, and that issued by October 12, 2021, for each of the 18 companies. The rightmost 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.

THE AMOUNT OF TIME THAT IT TAKES FOR A PATENT TO ISSUE IS IMPORTANT BECAUSE—OTHER THAN IN SOME NARROW SITUATIONS—A PATENT CANNOT BE ENFORCED (E.G., THE PATENTEE CANNOT RECOVER ANY MONETARY DAMAGES OR GET AN INJUNCTION) UNTIL IT HAS BEEN ISSUED.

Table 2 provides the definitions for and relationships between terms used in this article.

PROSECUTION TIME

As shown in Table 2, the prosecution time is the time between the patent's filing date and the patent's issue date. The amount of time that it takes for a patent to issue is important because—other than in some narrow situations—a patent cannot be enforced (e.g., the patentee cannot recover any monetary damages or get an injunction) until it has been issued. Furthermore, because the term for utility patents is now 20 years from the filing

[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 Part I of this article series.

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TABLE 1. Number of all issued patents and computer architecture filed between January 1, 1996, and December 31, 2020, and issued by October 12, 2021.

Company	Issued patents	Issued computer architecture patents
Amazon	15,653	8877
AMD+ATI	11,072	4539
Apple	26,869	11,867
ARM	2629	2240
Avago+Broadcom	14,731	6284
Dell+EMC+VMWare	20,231	4539
IBM	130,587	80,951
Intel	44,515	24,071
Marvell+Cavium	8531	5134
Microsoft	46,884	31,552
MIPS	273	271
NVIDIA	3872	3088
NXP+Freescale	11,675	3680
Qualcomm	28,292	9872
Renesas+Dialog+IDT+Intersil	14,247	4368
Samsung	131,946	35,948
SiFive	13	8
Via+Cyrix	1979	1324

date of the patent (or the filing date of an ancestor patent or patent application), a longer prosecution time reduces patent's lifetime. Table 3 shows the average (mean) prosecution time for all issued patents and for computer architecture patents only.

The first result from Table 3 is that the average prosecution time for all patents (middle column) ranges from 17.3 months (SiFive) to 49.7 months (MIPS), with a median value of 36.2 months. The prosecution time for SiFive may be deceptively low as compared to the other companies for at least a couple of reasons. First, SiFive only has 13 issued patents, so the average prosecution time may be artificially low as compared to if SiFive had more issued patents. Second, SiFive has the highest percentage of design patents[b] (15.4%), and design patents have a

[b]A design patent protects how an article looks, or its "ornamental appearance," while a utility patent protects how an article is used and works.

TABLE 2. Definitions of and relationships between key terms used in this article.

Term	Definition
Prosecution time	Patent's issue date – patent's filing date
Effective patent term	Patent's expiration date – patent's issue date
Expiration date	Minimum of (earliest U.S. ancestor, PCT filing date) + 20 years
Issue date	Filing date of the patent + prosecution time
Priority benefit	Patent's filing date – minimum of (earliest U.S. ancestor, PCT filing date)

significantly shorter average prosecution time as compared to all patents. For example, the median difference across all companies between the prosecution time for all patents and the prosecution time for design patents is 16.7 months. Third, because SiFive is a relatively new company, the only issued patents it has are those that have a short prosecution time. By contrast, if SiFive were an older, more established company, then patent applications with very long prosecution times (e.g., five years) would have enough sufficient time to issue and, concomitantly, would increase the average prosecution time. Fourth, because SiFive is a relatively new company, it benefits from across-the-board lower prosecution times in the last few years as compared to prosecution times in the early 2000s. More specifically, between 2000 and 2004, the average prosecution time ranged between 49.4 months and 52.4 months. By contrast, the average prosecution time between 2018 and 2020 (the timeframe in which SiFive had issued patents) ranged between 13.5 months (for patents filed in 2020) to 23.8 months (2018).

In general, and in no particular order, the prosecution time may be higher if examiners in a technical center are overburdened, the examiners have a higher rejection rate (which could require the applicant to spend more time addressing the examiner's concerns), slow responses by the applicants, a large number of claims, very broad claims, if the applicant filed a request for continued examination (i.e., a request to continue the prosecution of that application after a second office action as opposed to abandoning the application and starting over again), failure to use accelerated examination, etc.

The second result from Table 3 is that there does not appear to be a correlation between the number of issued patents a company has and the average prosecution time for those patents. More specifically, the Pearson correlation coefficient for the number of issued patents in Table 2 and the average prosecution time in Table 3 across all companies is –0.01,

TABLE 3. Mean prosecution time (in months) for all issued patents and for computer architecture patents.

Company	Mean prosecution time (all)	Mean prosecution time (comp arch)
Amazon	36.5	37.6
AMD+ATI	32.7	36.9
Apple	33.5	37.9
ARM	35.2	36.2
Avago+Broadcom	40.5	42.3
Dell+EMC+VMWare	36.4	37.3
IBM	35.9	38.4
Intel	38.1	40.0
Marvell+Cavium	32.0	32.4
Microsoft	43.0	46.0
MIPS	49.7	49.8
NVIDIA	47.5	48.4
NXP+Freescale	37.5	41.3
Qualcomm	40.5	41.7
Renesas+Dialog+IDT+Intersil	28.2	29.8
Samsung	33.5	37.2
SiFive	17.3	20.0
Via+Cyrix	35.9	38.5

which indicates that there is no correlation between the two.

Third, comparing the second and third columns in Table 3 shows that the average prosecution time for computer architecture patents is higher than the average prosecution time for all issued patents (which includes computer architecture patents). Using the z-test shows that there was a statistically significant difference, at 95% confidence level, between these two prosecution times for all companies except for Marvell, MIPS, and SiFive.

The difference in the prosecution times ranges from 0.13 months (MIPS) to 4.39 months (Apple). Given that 99.3% of MIPS's issued patents are classified as computer architecture patents, it is not surprising to see that the difference between overall prosecution time and the prosecution time for computer architecture patents only is essentially the same. With respect to Apple, the primary reason why Apple has the largest difference is because a significant percentage of Apple's patents are design patents (12.7%), which have a significantly lower prosecution time (an average of 18.9 months for Apple's design patents). By contrast, when excluding design patents, the average prosecution time for patents issued to Apple increases to 35.6 months, which reduces the difference between the prosecution times of all issued patents and computer architecture patents enough to put Apple's difference in the middle of the range of companies.

In general, and in no particular order, the prosecution time may be higher for computer architecture patents as compared to all issued patents because these patents may be more technical than the average patents, which then could require the examiners to spend more time reviewing the application and prior art, and/or require more time for the applicant to respond to issues than the examiner may raise; there may be more of a "patent thicket" for computer architecture patents such that it may take applicants more time and effort to narrow the claims to be allowable, yet have as large a scope as possible, etc.

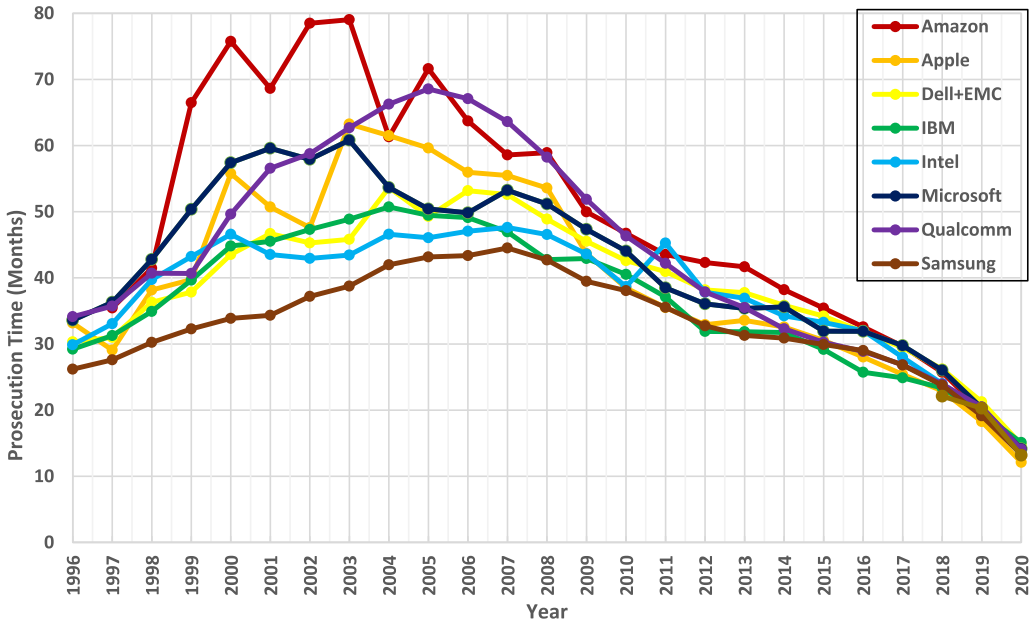
Figure 1(a) and (b) depicts the average (mean) prosecution time per year between 1996 and 2020 based on the year the patent was filed. (The rest of this article and the articles in this series will continue to arrange the patents in this manner.) Figure 1(a) presents the companies with the highest number of issued patents, while Figure 1 (b) presents the remaining companies. The curves for MIPS and SiFive are "cut-off" because MIPS did not have any issued patents from 2014 to 2020 and SiFive did not have any patents until 2018.

Figure 1(a) and (b) depicts similar results for all companies. Namely, the average prosecution time starts at approximately 30 months in 1996, slowly increases before peaking in 2001 to 2005, and then generally monotonically decreases until 2017 or 2018. The curve for Qualcomm is representative. In 1996, the average prosecution time for Qualcomm was 34.1 months. Between 1996 and 2005, the average prosecution time increased by more than 100%, from 34.1 to 68.6 months. Then, between 2005 and 2018, the average prosecution time decreased from 68.6 to 23.8 months. It is important to note that it is difficult to determine whether the prosecution times continued to decrease in 2019 and 2020, as compared to 2017 or 2018, because many patent applications that were filed in those years are still being examined. As such, if and when those patents issue, the average prosecution time may be higher than what is depicted for 2019 and 2020 in Figure 1.

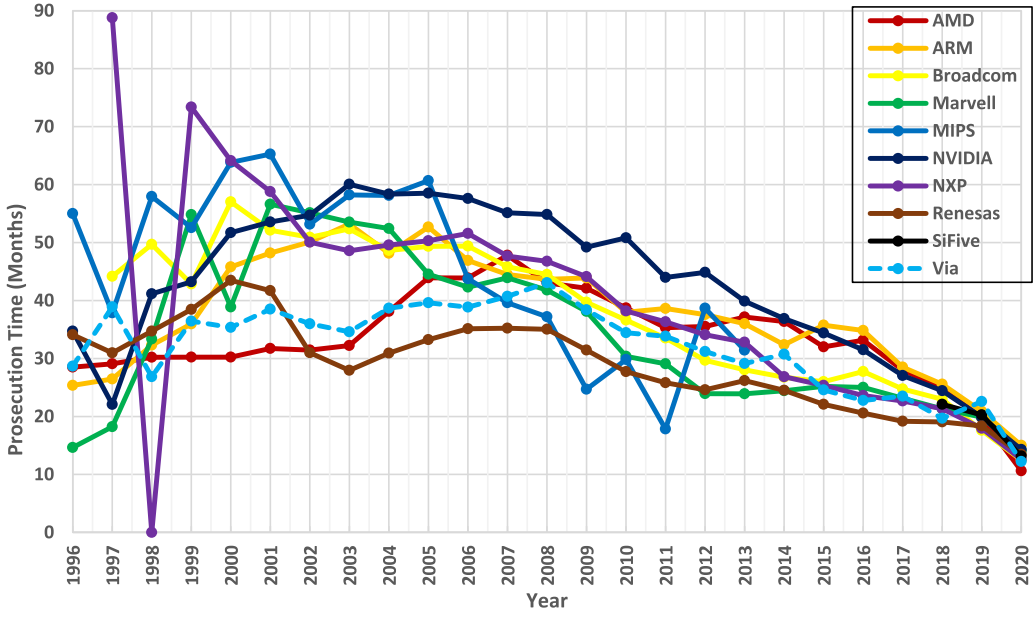
It is worth noting that the corresponding figures for the average prosecution time of computer architecture patents are generally similar to those in Figure 1(a) and (b).

EFFECTIVE PATENT TERM

As shown in Table 2, the "effective patent term" refers to the time between when a patent is issued and when it expires. This is the period of time during which a patent can be enforced.



(a)



(b)

FIGURE 1. Mean prosecution time (in months) for patents filed between 1996 and 2020. (a) Companies with the highest number of issued patents. (b) Companies with a lower number of issued patents.

A utility patent expires 20 years after the earlier of 1) the filing date of its earliest U.S. ancestor or 2) its Patent Cooperation Treaty (PCT) filing date, if any.[c] For example, if a patent does not have any ancestors, its expiration date is 20 years from its own filing date. But if a patent has a parent U.S. patent that was filed four years before its filing date, the child patent would expire 20 years from the filing date of its parent, or just 16 years from its own filing date. If the prosecution time is two years, then in the former case, where there

[c]The Patent Cooperation Treaty ("PCT") is an international agreement that facilitates filing a patent application in multiple participating countries.

TABLE 4. Mean effective patent term (years) for all issued patents and for computer architecture patents.

Company	Mean effective patent term (all)	Mean effective patent term (comp arch)
Amazon	16.1	16.0
AMD+ATI	16.9	16.5
Apple	17.0	16.8
ARM	16.7	16.6
Avago+Broadcom	15.3	15.0
Dell+EMC+VMWare	16.4	16.3
IBM	16.2	16.0
Intel	15.9	15.7
Marvell+Cavium	15.8	15.7
Microsoft	15.2	15.1
MIPS	14.3	14.2
NVIDIA	15.5	15.4
NXP+Freescale	16.6	16.4
Qualcomm	16.0	15.9
Renesas+Dialog+IDT+Intersil	16.4	16.2
Samsung	16.6	16.4
SiFive	18.5	18.3
Via+Cyrix	16.7	16.4

is no parent patent, because the patent issues two years after its filing date and expires 20 years after its filing date, the effective patent term of that patent is 18 years. But in the latter case, the expiration date is 20 years after the parent's filing date. Furthermore, because the child patent's filing date was four years after its parent and child patent's prosecution time was two years, the issue date of the child patent is six years after the parent patent's filing date. Therefore, the effective term of the child patent is only 14 years.

Table 2 depicts how to calculate the expiration date and the issue date. As can be seen by the mathematical relationships in Table 2, claiming priority to the earliest U.S. ancestor or PCT filing date reduces the effective patent term by virtue of having an earlier expiration date. But it also has the benefit of an earlier priority date, which allows it to predate any prior art that may have been created between the earliest U.S. ancestor or PCT filing date and the filing date of the patent-at-issue (hereinafter referred to as the "priority benefit," and also presented in Table 2). Similarly, a longer prosecution time also decreases the effective patent term, by delaying issue date. In other words, both the prosecution time and the priority benefit are inversely related to the effective patent term.

By contrast, the expiration date of a design patent is based on its issue date. For design patents that were issued before May 13, 2015, the term is 14 years. For design patents that were issued on or after that date, the term is 15 years. Because the term of a design patent is based on the issue date, the prosecution time does not reduce the patent term. As such, the effective term of a design patent is either 14 or 15 years. As such, this section will focus on the effective patent term of utility patents.

Table 4 tabulates the average (mean) effective patent term for all issued utility patents and for computer architecture patents only.

The results in the middle column of Table 4 show that the effective patent term of these 18 companies ranges from 14.3 years (MIPS) to 18.5 years (SiFive). Of the remaining companies, the effective patent terms for Microsoft, Broadcom, NVIDIA, Marvell, and Intel are between 15 and 16 years while Qualcomm, Amazon, IBM, Renesas, Dell+EMC, Samsung, NXP, Via, ARM, and AMD have effective patent terms between 16 and 17 years. Apple's effective patent term for all issued utility patents is 17.0 years.

SiFive's average effective patent term of 18.5 years is more than a full year longer than the company with the next highest average effective patent (Apple, 17.0 years). The most likely reason that SiFive's average effective patent term is so much higher than those of the other companies is because SiFive is a new company. More specifically, as discussed previously, because SiFive is a new company, the only patents that have been issued so far are those with a shorter-than-normal prosecution time. Furthermore, none of SiFive's patents claim priority to an earlier patent, which increases the effective patent term.

By contrast, the effective patent term for MIPS is almost one year shorter than the company with the next lowest average effective patent term (Microsoft, 15.2 years). The primary reason why MIPS has the lowest effective patent term is because the average prosecution time of its patents is very high, namely, 4.1 years. The second reason is because MIPS also has the largest average priority benefit (1.6 years).[d]

Comparing the second and third columns in Table 4 shows that, for the most part, the effective patent terms for all issued utility patents and computer architecture patents are very similar. The only company that had a difference greater than ± 0.25 years was AMD (all patents – computer architecture patents $=$

[d]A future article in this series will analyze the benefit of claiming an earlier patent.

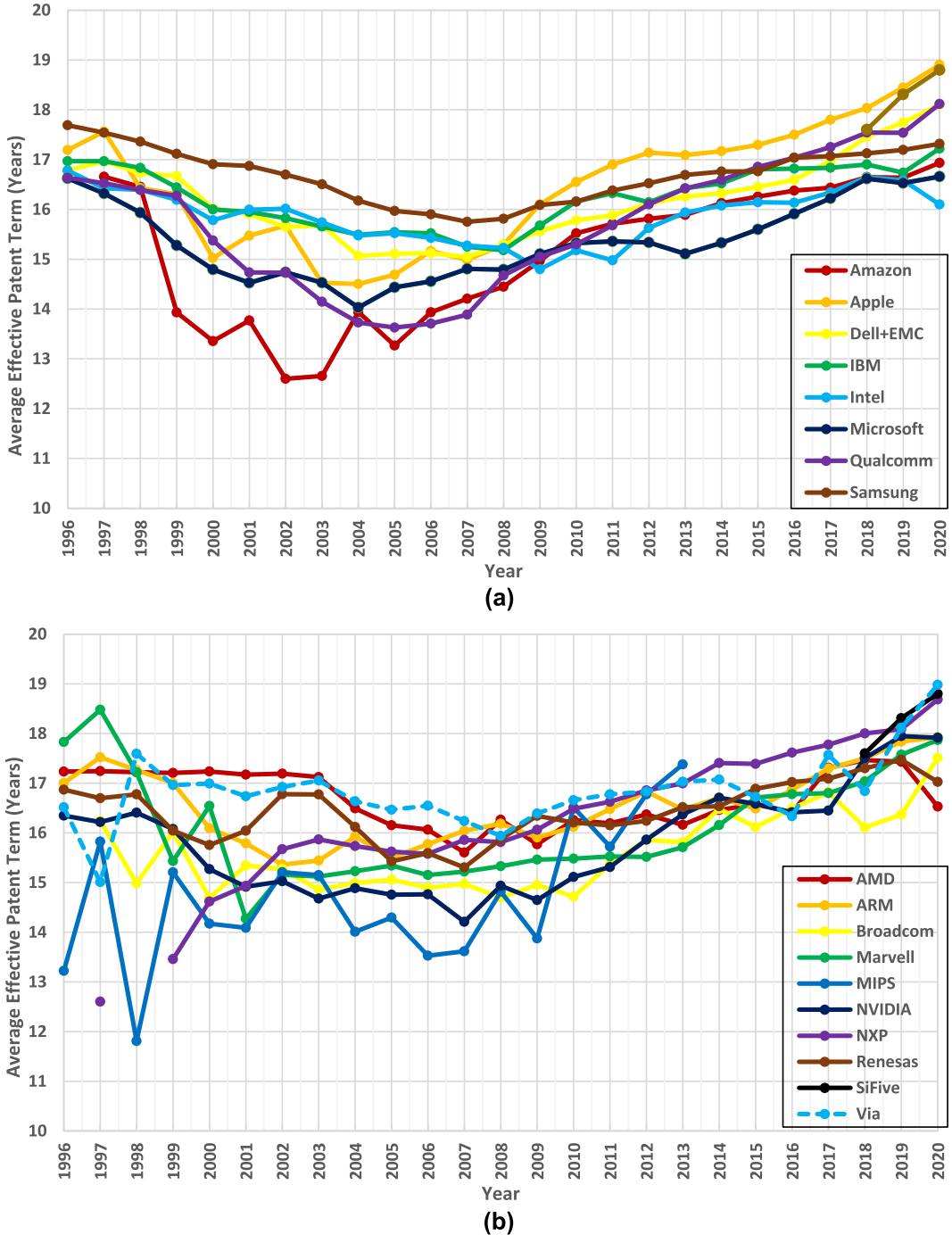


FIGURE 2. Mean effective patent term (in years) for patents filed between 1996 and 2020. (a) Companies with the highest number of issued patents. (b) Companies with a lower number of issued patents.

0.41 years). The primary reason that computer architecture patents for AMD have a shorter effective patent term, as compared to all issued utility patents, is because the former has an average priority benefit of 0.34 years (as compared to 0.0 years for all issued utility patents), which concomitantly decreases the former's effective patent term.

Figure 2(a) and (b) depicts the average (mean) effective patent term for all issued utility patents between 1996 and 2020 based on the application year

of each issued patent. As was the case for Figure 1(a) and (b), Figure 2(a) presents the companies with the highest number of issued patents, while Figure 2(b) presents the remaining companies. Again, the curves for MIPS and SiFive are "cut-off" because MIPS did not have any issued patents from 2014 to 2020 and SiFive did not have any patents until 2018.

The results in Figure 2(a) and (b) show that, in 1996, the average effective patent term was between approximately 16 and 18 years. From 1996 to 2002–2007 (depending on the company), the average effective patent term decreased to their lowest values, ranging from 11.8 years (MIPS in 1998) to 15.8 years (Samsung in 2007). Then, from 2002 to 2007 (depending on the company), the average effective patent term generally increased, such that the effective patent term was over 16 years for all companies in 2020. It is important to note that the average effective patent term in recent years is probably artificially high because the prosecution time is artificially low as many patent applications are still pending and only the applications with the shortest prosecution times have been issued thus far.

The results for a couple of companies in Figure 2(a) and (b) stand out. First, the average effective patent term for Amazon is extremely low between 1999 and 2006. More specifically, Amazon's average effective patent term ranged from 12.6 to 13.9 years during this timeframe. The primary reason that the average effective patent term is this low is primarily because the prosecution times were high (as opposed to the priority benefit being high). Amazon's average prosecution time during this time frame ranged from 5.1 years (2004) to 6.5 years (2002), while the priority benefit during this timeframe only ranged from 0.3 to 0.9 years.

The average effective patent term for MIPS between 1996 and 1999 varies significantly from year to year. More specifically, the average effective patent term in 1996, 1997, 1998, and 1999 was 13.2, 15.8, 11.8, and 15.2 years, respectively. The likely reason for this was that in 1996 and 1998, there were only one and two issued patents, respectively. As such, the long prosecution times—and the high variability in the effective patent term between 1996 and 1999—might simply be due to a small number of patents in 1996 and 1998.

Similarly, the average effective patent term for NXP in 1998 is 12.6 years. This relatively short term is due to a very long average prosecution time of 7.4 years, which, in turn, appears to be a function of a small sample size of just one issued patent.

Finally, it is worth noting that the corresponding figures for the average effective patent term of computer architecture patents are generally similar to those in Figure 2(a) and (b). The most notable difference is that the effective patent term of Amazon's computer architecture patents between 1999 and 2006 is higher than Amazon's average effective patent term for all issued utility patents for the same timeframe. The difference in the average effective patent terms (all patents – computer architecture patents) between 1999 and 2002 was −2.3, −2.5, −1.8, and −1.2 years. But this difference was smaller between 2003 and 2006, namely, −0.3, −0.5, −0.4, and −0.7 years. The differences in the average effective patent terms between 1999 and 2002 could be the result of very small sample sizes, namely, Amazon only filed 25, 21, 22, and 17 applications between 1999 and 2002 that resulted in an issued utility patent and, of those, only 10, 5, 4, and 3, respectively, were computer architecture patents.

TABLE 5. Percentage of eligible patents with at least one day of term adjustment.

Company	Percentage of eligible patents with 1+ day term adjustment
Amazon	68.1%
AMD+ATI	50.7%
Apple	57.8%
ARM	66.7%
Avago+Broadcom	68.4%
Dell+EMC+VMWare	71.7%
IBM	61.6%
Intel	57.7%
Marvell+Cavium	57.3%
Microsoft	75.7%
MIPS	73.6%
NVIDIA	76.6%
NXP+Freescale	67.0%
Qualcomm	68.5%
Renesas+Dialog+IDT+Intersil	48.8%
Samsung	63.6%
SiFive	18.2%
Via+Cyrix	74.3%

IMPACT OF PATENT TERM ADJUSTMENT

In order to compensate a patentee for any delays due to the U.S. Patent and Trademark Office (PTO), 35 U.S.

TABLE 6. Mean patent term adjustment (years) for all eligible issued patents and for eligible computer architecture patents.

Company	Mean term adjustment (all eligible)	Mean term adjustment (comp arch eligible)
Amazon	0.71	0.69
AMD+ATI	0.56	0.82
Apple	0.69	0.79
ARM	0.71	0.77
Avago+Broadcom	1.05	1.14
Dell+EMC+VMWare	0.74	0.75
IBM	0.82	0.95
Intel	0.67	0.79
Marvell+Cavium	0.69	0.71
Microsoft	1.10	1.12
MIPS	1.03	1.04
NVIDIA	1.20	1.25
NXP+Freescale	0.70	0.88
Qualcomm	0.83	0.91
Renesas+Dialog+IDT+Intersil	0.41	0.56
Samsung	0.72	0.86
SiFive	0.03	0.04
Via+Cyrix	0.97	1.12

C. § 154(b) authorizes the PTO to adjust the term of the patent. The amount of the adjustment, if any, extends the term of the patent beyond the original expiration date. For example, suppose a patent had a term adjustment of 30 days and would have expired on March 1 without said adjustment. With the adjustment, the patent then will actually expire on March 31. By contrast, because the term of a design patent begins when it is issued, design patents are not eligible for term adjustment.

Table 5 shows the percentage of utility patents that were eligible for a patent term adjustment that had a patent term adjustment that was at least one day long.[e] The patents that had 0 days of adjustment, i.e., did not receive an adjustment, account for the remaining percentage of patents.

The results in Table 5 show that percentages span a very wide range. SiFive has the lowest percentage (18.2%). This result is not particularly surprising for two reasons. The first reason, as was the case for the other analyses, is that SiFive is a new company. More specifically, for the reasons described previously, because SiFive's issued patents likely have an artificially low prosecution time, this means that these patents are less likely to receive any patent term adjustment because there were no PTO-related delays that delayed the patent's issuance. Second, because the prosecution times are lower in recent years as compared to the early 2000s, there are generally less PTO-related delays that might result in an adjustment of the patent term.

The percentages for the remaining companies range from 48.8% (Renesas) to 76.6% (NVIDIA). There does not appear to be any correlation between the percentage of patents receiving a patent term adjustment and the number of issued patents. For example, the Pearson correlation coefficient is 0.06, which indicates no correlation.

Table 6 tabulates the average (mean) amount of patent term adjustment for all eligible issued utility patents and for eligible computer architecture patents only.

The results in the middle column show that the average patent term adjustment for all patents ranges between 0.03 years (SiFive) and 1.20 years (NVIDIA). Although the magnitude of these adjustments is relatively small, it is important to remember that because approximately 25%–50% of the eligible patents received no adjustment, the patents that did receive a patent term adjustment could be significantly higher than the average values.

Comparing the results in the second and third columns shows that the average patent term adjustment for computer architecture patents is slightly higher for all companies except Amazon, ranging from 0.02 to 0.18 years. This result is not particularly surprising given that the results in Table 3 show that the average prosecution time for computer architecture patents is higher than that for all issued utility patents. For Amazon, the average amount of patent term adjustment for all patents is slightly higher (0.02 years) than the average amount of patent term adjustment for computer architecture patents.

Comparing the results in Table 4 with the results in Table 6 provides a ballpark estimate of the percentage increase in the effective patent term due to patent term adjustments. This is only a ballpark estimate as Table 4 provides results for all issued patents while Table 6 provides results only for patents eligible for a patent term adjustment. Although the denominators in both tables have relatively similar values for all companies, they are still different. As such, comparing Tables 3 and 5 only provides a ballpark estimate, albeit likely a relatively accurate one. It is important to mention that, because the results in Tables 3 and 5 are

[e]For some eligible patents, due to errors that appear to be related to incorrect OCR and/or lack of a searchable pdf, I was not able to automatically extract the patent term adjustment. These problems appeared to affect less than 5% of all eligible patents for all companies.

both averages, the percentage increase in the effective patent term due to the patent term adjustment could vary significantly for any individual patent.

BASED ON THESE RESULTS, IT APPEARS THAT, ON AVERAGE AS COMPARED TO ANY INDIVIDUAL PATENT, THE PATENT TERM ADJUSTMENT INCREASES THE EFFECTIVE TERM IN A NONNEGLIGIBLE MANNER.

With those caveats in mind, adding the average patent term adjustment in Table 6 to the average effective patent term in Table 4 increases the average patent term by 0.2% (SiFive) and 7.8% (NVIDIA) for all patents. The range of percentage increase for the computer architecture patents is very similar, namely, 0.2% (SiFive) and 8.1% (NVIDIA). That said, the percentage increase in the effective patent term for companies between SiFive and NVIDIA can be different for computer architecture patents as compared to all issued patents. For example, for AMD and for all patents, the percentage increase in the effective patent term due to patent term adjustment is 3.3%, but for computer architecture patents only, the percentage increase is 5.0%. Similarly, the corresponding percentages for NXP are 4.2% (all) and 5.4% (computer architecture). By contrast, for Microsoft, the corresponding percentages are 7.3% and 7.4%, respectively.

Based on these results, it appears that, on average as compared to any individual patent, the patent term adjustment increases the effective term in a nonnegligible manner.

In Part III of this series, I will examine the number and type of claims for these companies for patents filed between January 1, 1996, and December 31, 2020.

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