Chapter 4

VALUATION OF A TECHNOLOGY PATENT–SCOPE, DURATION, AND ROYALTY

4.1. Introduction

The owner of a patent receives value from his patent in several ways. First, the patent owner can exploit the patent themselves to the legal exclusion of others. Second, the patent owner may sell all rights to the patented invention. Third, he may license the patent to others. The value of the patent depends on several factors including its scope of application (economic, technological, and legal), its duration of application (legally limited to a fixed period of time but often constrained by non-infringing superior substitutes, and by its royalty or profit rate. The value of a patent to its owner is clearly constrained by the availability of substitutes. Substitutes limit the value of the patent by affecting the scope, duration, and royalty a patent owner may expect to receive. The determination of these influences on a particular patent is hardly ever a generic exercise. More often than not the value of a patent is determined on a case by case basis.

The purpose of this chapter is to establish the value of a particular patent and illustrate the role of scope, duration, and royalty rate in determining this value. The patent I examine was awarded to the computer manufacturer Acer in 1991.

By 1990, upgrading of personal computers ("PCs") had become common.[1] Consumers wanted a method to protect their investment in PCs against technological obsolescence. In order to meet this need, most major manufacturers developed their own schemes for providing upgrades. In 1991, Acer applied for and received two U.S. patents (5,455,927, con't of Aug. 22, 1991, "dual-

[1]Upgrading computers from XT/286 to Pentium machines is discussed in "Tips from the NERD," July 7, 1996 at *http://www.computernerd.com/tips4old.htm*. This author does not recommend upgrading 386 systems because of modest speed improvements and serious residual limitations.

socket") and (5,551,012, con't of Apr. 22, 1991, "single-socket").[2] Acer has referred to these patents in its product documentation as the "Chip Up" technology.[3]

The Chip-up technology pertains to upgrading a computer by adding a second (typically faster) control processing unit (CPU) in a socket reserved for the upgrade. A user could upgrade his computer by adding the newer CPU in the reserved socket at any time. As I discuss below, using a primary socket for the main CPU and a secondary socket reserved for the upgrade implies that Acer's system is a dual-socket technique. The sockets that receive the processors in Acer's design are contained on the main circuitry board (motherboard) of the computer.

The Chip-up technology patent specifically was designed to upgrade Intel 80386 (386) computers by a specific method. This patent would not have applied to computer upgrades using non-infringing designs (e.g. modular, daughterboard, card, cartridge, overclocking, etc.) and would not have applied to upgrades of Intel 80486 (486) and Intel 80586 (Pentium) computers. I address these points in turn. First I discuss non-infringing designs which provide 386 computer owners with the ability to upgrade their computers. Second, I discuss upgrades of 486 and Pentium computers.[4]

The value of the Chip-up technology is demonstrated to be small due to the availability of substitutes and the limited applicable scope. The remainder of this chapter is divided into several sections. In Section 4.2, I discuss the scope of the Acer patent. In Section 4.3, I discuss duration issues. In Section 4.4, I discuss the reasonable royalty rate for the Chip-up technology. In Section 4.5, I present my conclusions.

4.2. Scope Limitations

Upgrading a computer might involve enlarging disk drive storage, adding Random Access Memory (RAM) or cache-memory to the motherboard, adding a math coprocessor to speed up numerical calculations or changing the 386/387 pair to specialized chips for computer aided design. A consumer could also upgrade a computer by overclocking the existing CPU.[5]

[2]The validity of the Acer patents has not been established to the best of my knowledge. Each Acer patent refers to substantial prior art. Additionally, Intel's patent (5,410,726, con't of Apr. 18, 1991, dual-socket upgrades) and Advanced Logic Research's patent (5,297,277, August 2, 1989, automatic enablement) and Advanced Micro Devices' (4,967,346, March 14, 1988, automatic enablement) might establish prior art relevant to the Acer patents and were not cited by the patent office in connection with the Acer patent.

[3]The name "Chip Up" is apparently trademarked (Trademark 1,730,271, 11/3/92, Trademark Register, 39th Edition, 1997).

[4]I refer to the Intel 80386 CPU as a 386 and the Intel 80486 CPU as a 486. The math coprocessor versions of these chips have model numbers ending in 7. Thus, the Intel 80387 coprocessor (387) is the math coprocessor for the 386.

[5]Overclocking is explained in *http://www.sysoopt.com/ocexp.html*.

I mention these non-CPU upgrade paths because different consumers would find some upgrades more advantageous than others.[6] For instance, many applications were slowed by poor hard disk performance or insufficient disk storage space. Other applications operated slowly due to too little RAM in the computer. Some consumers did require a speed increase in their CPU. However, independent of processor speed, the preferred upgrade path for many of these consumers was a non-CPU upgrade. For example, for a great many consumers, a coprocessor to do mathematical calculations would have been the most logical upgrade. In fact, most 386 motherboards contained one or two empty sockets for coprocessors. In most cases, these coprocessors were used for arithmetic processor upgrades (adding a 387 or Weitek chip). However, in some cases the sockets were used for other CPU upgrades (e.g. the Intel CAD pair[7]

4.2.1. The Variety of Computer Upgrade Technologies

Since the first generation of IBM PCs, it was common practice to use empty sockets for motherboard upgrades (e.g. the 8087 paired with the 8086, the 80287 paired with the 80286 and the 80387 or the Weitek paired with the 80386). Replacing existing chips with higher speed versions or overclocking (running a CPU at a higher speed than it was rated) were other common upgrade paths for consumers who did not choose a full “generation skip." A generation skip is defined as a movement between families of CPUs such as upgrading from a 386 to a 486. It is a generation skip upgrade that Acer’s design contemplated.

The Acer design was not the only available design to accomplish a generation skip upgrade. Some manufacturers used a modular upgrade that utilized a module or separate component on which the CPU and its replacement could be interchanged in the computer. Some manufacturers relied on cards which plugged into the computer’s bus, often using proprietary high-speed bus interfaces to maximize the computer’s throughput. Other manufacturers relied on third-party daughterboard upgrades that required removing the existing CPU and fitting a small upgrade component into the old socket (this is known as the single-socket upgrade method). Still others adopted a technology such as Acer’s that left an additional empty socket for the upgrade.

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[6] Upgrading a PC (especially a motherboard upgrade) was never considered an easy process. For instance, *Byte* (April 1, 1991, Vol. 16, No. 14, pp. 283–286), noted that replacing a CPU is a “nightmare," recommending only “the most grizzled hardware veterans" attempt it. Problems with user upgrades include breaking pins on the old or new CPU, destroying a part with static discharge, BIOS incompatibilities, failure of the system to function after the upgrade, software incompatibilities, etc. These issues made CPU upgrades a non user-friendly task. Consequently, the market for upgrades was always a small one.

[7] See e.g. “Intel Coprocessor to Boost CAD performance on 386 PCs”, (*PC Week*, Feb 17, 1992, Vol. 9, No. 7, p. 30).

Single-socket upgrades have been around since the beginning of personal computers. Daughterboards were designed to replace the existing CPU, in its socket, with upgraded CPUs.[8]

Acer's technique was identical to a coprocessor upgrade in that he left an empty socket for CPU additions to enhance performance. The 8086 system generally left one empty socket for the coprocessor. The 80286 system left one empty socket. The first 386 computers generally left two empty sockets - one for the existing 287 math coprocessor and another for the yet to be released 387 math coprocessor. Most, 386 systems also left two empty sockets. The first empty socket was for a 387 math coprocessor while the second was left for the Weitek coprocessor. Some dual CPU systems provided both I860 (Intel) and 80X86 (80286 and 80386) CPUs on the same motherboard, although only one processor had control at a time. In fact, there was nothing new in Acer's patent with regard to having empty sockets on the motherboard for the permanent or transitory use of a second processor.[9]

Mirecki (1987) discusses a method by which a personal computer's microprocessor is replaced by a more capable one. The author notes that if the original CPU remains, "the accelerator is called a coprocessor. This does not imply that the two CPUs dynamically share the workload. In most cases only one CPU is active at any given time, and the switch between them is performed by the user." This description is precisely the coprocessor solution adopted by Intel for the original PC and for the IBM XT and for all subsequent Intel based products.[10]

4.2.2. Coprocessors and Empty Slots

The coprocessor socket, available in nearly all PCs from the 8086 generation onward,[11] had full access to the CPU bus and adequate control lines to disable the main CPU.[12]

Intel's "vacant socket" technique for upgrading 486 systems relied solidly on prior art to provide an upgrade for 486 systems and Pentium systems.[13]

[8] Acceleration upgrades for the 8088 are discussed, for instance, in Manildi (1988).

[9] Another example is the Intel hyper-cube. Intel's hyper-cubes use many (16, 64, 256) CPUs in their own sockets in a parallel processing system. A user would upgrade this architecture by adding additional CPUs.

[10] Mirecki (1987) also discusses daughterboards and other plug-in single socket coprocessor upgrade solutions.

[11] The first 8086 was released in the early to mid 1980s.

[12] See *Electronic Engineering Times* (July 1, 1991).

[13] Intel (1997) describes its Intel 486 Processor Upgrades by socket type (*http://www.intel.com/overdrive/-unbrand/486.htm*), its Intel 386 systems upgrades at *http://www.intel.com/overdrive/unbrand/386.htm*. Its upgrade for Pentium systems is described at *http://www.intel.com/overdrive/unbrand/pentpso.htm*. Intel notes that "As the market has transitioned to Pentium processor technology and demand for upgrades based on older technologies has declined, Intel OverDrive processors based on Intel 486 technology have been phased out." The key point is that the newer technology makes the older technology less attractive even as an upgrade.

Intel's upgrade method reused the existing coprocessor socket for coprocessor or CPU upgrades. By contrast, Acer's technique leaves the original CPU and coprocessor sockets and adds an additional socket reserved for the upgrade. Acer's dual-socket approach is therefore minorly different from Intel's approach. Intel's approach reused an existing empty socket reserved for coprocessor upgrades whereas Acer's approach added an additional empty socket.[14]

A review of the technology shows that 486 systems and Pentium systems were upgraded by using well established prior art and by single-socket upgrade solutions.[15] It is for this reason that the Acer patent would not apply to any system beyond 386 based systems.[16]

4.2.3. Proprietary Upgrade Methods

Most brand manufacturers had their own schemes for computer upgrades. It is true that, in many cases, the consumer was locked into the original manufacturer for the upgrade. However, the consumer nonetheless trusted that the brand manufacturer would provide a working upgrade solution and would support the PC under its original warranties and conditions.

In *Electronic Engineering Times* (1991)[17] the technology known as EISA II was touted as defining an emerging standard for plug-in CPU boards. According to this article, Compaq, AST, ALR, Northgate, NEC, Hyundai, Blackship Computer Systems, Tandon, Acer, Altos, Copam, Arche Technologies, and CAF had all announced proprietary modular ISA and/or EISA systems. Additionally, Alpha Systems, Hauppauge Computer Works, American Megatrends and Fujikama had announced modular upgradeable motherboards. Further, Intel is reported in this article to have introduced a standard modular connector for CPU cards (the P3 interconnect). The article lists five additional motherboard manufacturers that were reported to have products or promises to develop motherboards around the emerging Intel standard. The Intel standard (P3) was *not* a dual-socket design. The *Electronic Engineering Times* article

[14] Intel Senior Vice President David House noted that "starting with the new 486SX CPU board, the coprocessor is no longer just a math coprocessor socket–it has become a universal upgrade socket." House also noted that Intel would introduce several products that fit into this socket to increase not only math performance but also overall system performance. House said, "Some systems today have an upgrade path. Today you can insert a 487 math chip to boost math performance. Next year, you'll be given a second upgrade choice: a two-times clock CPU upgrade that will run at 40 MHz internally."

[15] See "Has OverDrive Outlived Its Usefulness?" *PC Week* (October 13, 1997) for a discussion of the Overdrive technology which Intel offered to fill its empty socket and one author's view of the motivation to provide this infrequently used upgrade option.

[16] Intel's patent on the vacant socket technique is apparently contained at United States Patent 5,410,726, Bouquai, *et al.* "Upgrading the microprocessor of a computer system without removal by placing a second microprocessor in an upgrade socket." Intel's original application date for this patent is April 18, 1991.

[17] See *Electronic Engineering Times* (October 28, 1991, Issue 665).

also states that 65 percent of manufacturers were providing a modular upgrade system.[18]

4.2.4. Dual-Socket Technology Was Rare

My extensive searches of *Byte* magazine and my review of articles published in other computer magazines from the 1989-1993 period showed few designs for upgradeable systems using the dual-socket approach. This is a very significant finding. If PC manufacturers or motherboard manufacturers used dual-socket upgrade designs and if this were an important selling feature to consumers then I would have expected to see extensive disclosures in product advertisements of this upgrade method. On the contrary, very few manufacturers based an upgrade on the dual-socket technology and none of the major manufacturers other than Acer adopted this technique. For new technologies, such as computer upgrades, the reputation or brand name of the manufacturer is a very important aspect of the purchase decision for the consumer. Without the strong reputation or brand name of a major PC manufacturer, the dual-socket upgrade technique would in and of itself be of limited value as it would play a limited role in promoting consumer sales.

Atman systems used a dual-socket design in 1992 while Lodestar used a dual-socket design during the period 1991–1993 (*Byte* advertisements). Deico's "predator" motherboard used a dual-socket in April 1992, as did the HIPPO upgradeable server motherboard (JYS Enterprise), Blue Star 386/33 system in May 1992, and Poly 3186/Zen system in Feb 1992. Additionally, *PC Sources*, April 1992 discloses that Peach Computer Systems had an upgradeable dual-socket motherboard. Acer America's Acer Power 386SX is disclosed to use a dual-socket upgrade system in *PC World* (January 1992). An earlier product announcement for the Acer 386SX appears in *InfoWorld*.[19]. However, this article states that "the new system features an upgrade socket that can accept either the 20 MHz 486SX or the 487SX from Intel." To the extent that Acer's dual-socket upgrade method uses the coprocessor socket, it would appear to be closer to the Intel coprocessor upgrade method and would therefore be covered under Intel's patent.

In sum, Acer Computer and Lodestar Computer were the only manufacturers with any name recognition that sold dual-socket upgradeable systems. Of lesser stature were Deico (motherboards after April 1992), Blue Star (systems

[18] An article in *PC Week Buyer's Guide* (July 29, 1991), reports that ALR, AST, Club American, Compaq, Dell, Digital Scientific, Micro Express, Northgate, Reply, Touch Micro Technologies, and Unisys all use a modular architecture. Everex is disclosed to use a daughterboard upgrade system in "20 Top Upgrades–Has Your PC Seen Better Days" and American Megatrends (AMI) is disclosed to use a daughterboard upgrade system in "AMI Offers Upgradeable 386 Motherboard," *InfoWorld* (July 2, 1990, Vol. 12, No. 27, p. 25).
[19] See *InfoWorld* (October 14, 1991, Vol. 13, No. 41, p. 28)

after May 1992), Peach Computer Systems (motherboards after April 1992) and Atman Systems (motherboards after September 1992).

Data from StoreBoard reveal that AST, ALR, Compaq, NEC, Hyundai, IBM, and Everex had the highest sales volume among PC manufacturers in late 1991 and 1992. None of these manufacturers used a dual-socket system. Instead, each provided their own modular proprietary upgrades. Other "brand" manufacturers of the day included EPSON, Leading Edge, Hewlett-Packard, Toshiba, and Zenith. Available evidence suggests that their computers provided no upgrade path for their systems and instead relied on after-market designs for customer upgrades. Of the top twenty personal computer companies in unit sales, Acer was the only company to use a dual-socket design for some of its personal computer systems.

As I discussed above, 65 percent of PCs provided upgrade solutions. Of those that I have identified as providing some upgrade path, only two of twenty-three used a dual-socket design.[20] Furthermore, the only users of dual-socket designs appear to have been Taiwanese motherboard manufacturers. Approximately eleven percent of U.S. imports of all computer products came from Taiwan (U.S. Department of Commerce and EIA Market Research Department). If Acer's design had been adopted by 50% of Taiwanese manufacturers, then roughly 5.5 percent of the non-branded PC systems of the day would have used the dual-socket design.

4.3. Duration Limitations

In this section, I review the rapid advances of CPU technology, and show how newer technology quickly displaces older technology. Consumers faced with rapid technological changes come to expect significant price decreases in older technology as newer technology is introduced. The consequence of the rapid decline in CPU prices coupled with newer systems with substantial increases in computing power is that the value of the upgrade option embodied in the dual-socket motherboard is diminished over time. Indeed, the second-socket option in the dual-socket motherboard will have its highest value as an upgrade from 386 to 486 technology when the price of 486 CPUs is also at its highest point and expected to decline the most. As the price of 486 CPUs decline, the value a consumer places on a second socket system in a dual-socket

[20] I refer to approximately 23 systems (whether motherboards or full computers) in the summaries above. I have given less weight to Dataexpert, ATMAN, DEICO, Bluestar, and PEACH and combined them into one manufacturer as their products appear only in mid to late 1992 or 1993. Also, none of the latter were disclosed in the *PC Week Buyers Guide* (July 29, 1991) review article. However, I give them collectively the same weight as Lodestar. Lodestar had systems for sale during the full period 1991-1993. Lodestar also had advertising in *Byte* magazine even though they were missed in the *PC Week Buyer's Guide* table.

motherboard also declines.[21] This short interval during which consumers place a significant value for the second socket in the dual-socket system, in conjunction with the rapid decline in the 486 personal computer systems price, leads me to conclude that the time interval when dual-socket motherboards would have been desired by consumers was short. This implies that the appropriate or reasonable royalty value for the design would have declined rapidly over time as the option value faded rapidly.

In Table 4.1, I display a selected history of microprocessor introduction and other significant dates from August 1986 through November 1995. In Figure 4.1, I show the timeline for Intel's processors. Figure 4.1 is based on the information presented in Table 4.1.

Table 4.1. Selected Processor History*

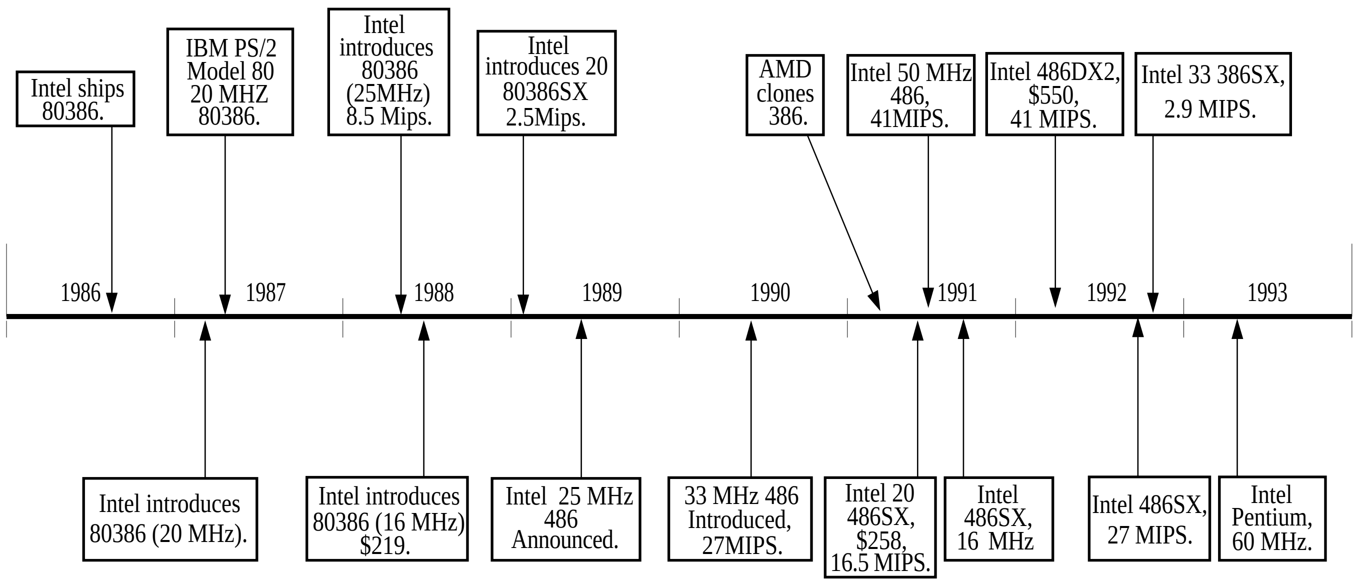
August 1986	Intel Ships 80386
February 1987	Intel Introduces 80386 (20 MHz)
April 1987	IBM PS/2 Model 80 20 MHz 80386
April 1988	Intel Introduces 80386 (25 MHz) 8.5 MIPS
June 1988	Intel Introduces 80386X (16 MHz) $219
January 1989	Intel Introduces 20 80386X 2.5 MIPS
April 1989	Intel 25 MHz 486 Announced
April 1989	Intel 33 MHz 386 DX Announced
June 1989	First 486 PC Introduced, 25 MHz, 486, and IBM MCA Bus, $18,000
May 1990	33 MHz 486 Introduced, 27 MIPS
March 1991	AMD Clones 386
April 1991	Intel 20 MHz 486SX, $258, 16.5 MIPS
June 1991	Intel 50 MHz 486, 41 MIPS
September 1991	Intel 486SX, 16 MHz
March 1992	Intel 486DX2, $550, 41 MIPS
September 1992	Intel 486SX, 27 MIPS
October 1992	Intel 33 386SX, 2.9 MIPS
March 1993	Intel Pentium, 60 MHz
March 1994	Intel 486 DX4 75, 100 MHz
November 1995	Intel Pentium Pro, 100 MHz

*Source: "Chronology of Events in the History of Microcomputers 1994-1997," and "Processor Timeline," *http://zdnet.com/pcmag/features/cpu/cpu12.htm*.

Importantly, between April 1991 and June 1991, Intel introduced its 50 MHz 486 processor. This occurred only one year after it introduced the previous standard, the 33 MHz 486 processor. The 486 CPU had been announced as early as 1989. But, in 1991, the introduction of the AMD 386 clone and faster

[21] Moore's Law states that microprocessor CPU speeds will double every 18 months. Thus far this empirical regularity has remained fairly accurate. The consequence of Moore's Law is that the price of a CPU of constant speed should nearly halve every 18 months as well. Often the price declines occur more rapidly.

Figure 4.1: Intel Processor Timeline



Source: Based on Table 4.1

486 CPUs caused the previous technologies' prices to decline rapidly. In Figure 4.2, I display the specifications and speeds of successive generations of Intel processors using the standard iCOMP index.

Each CPU generation brought faster and faster processing power, making older technologies obsolete. This pattern of newer technologies supplanting older technologies and causing their prices to fall is discussed in *InfoWorld* (April 8, 1991).[22] The effect on the value of a rapidly changing market of accelerator boards (and, more generally, upgrade options) is discussed in *Personal Computing* (August 1, 1989).[23]

4.3.1. A Product Lifecycle Model for CPU Sales

Frank Bass (Bass (1969)), in a pioneering study, introduced a simple and now standard model of consumer durable purchases. In the Bass model, there are innovators (those who buy first and for whom price is not a substantial barrier) and adopters (those who follow based on the innovator's experience with the product). Given a fixed number of potential buyers, Bass shows that product sales will generally rise at an increasing rate, eventually plateau and then fall to zero as the stock of potential buyers declines.

The Bass model has been modified by other authors to include advertising and price. In the case of price, it has been shown that it is optimal for the seller to "skim-price." In skim pricing, the product price, when first introduced, is set at a high level (since demand is inelastic for the innovators) and is eventually lowered to increase the number of potential buyers. Many consumer goods and computer products exhibit this pattern.

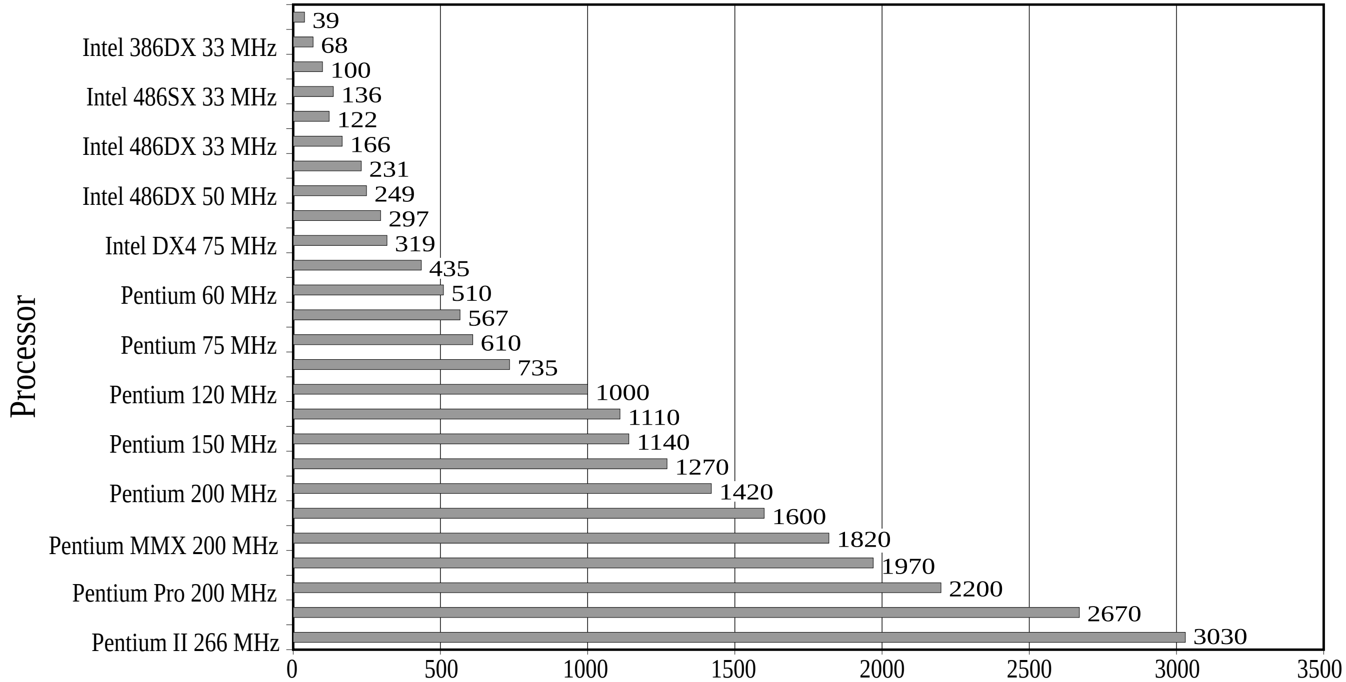
In Norton and Bass (1987) a variant of the product lifecycle model was introduced to explain the sales path for older technology when newer technologies are introduced.[24] Figure 4.3 is adapted from the Norton and Bass paper. This figure shows that sales of the first generation product rise and then fall. A similar pattern is seen for the second-generation product. However, the decline in the first generation is affected by introducing the second-generation technology. This is known as the overlapping product lifecycle model. Interestingly, when Norton and Bass applied their model to an actual empirical example they used successive generations of dynamic random access memory

[22] See "486SX Will 'Cannibalize' 386 Sales, Leaving the 386SX Market Strong," *InfoWorld*, April 8, 1991, Vol. 13, No. 14, pg. 24.

[23] See "What's New in Accelerator Boards–Challenged by Low-Cost Computers, Accelerator Boards have Become Less Expensive and Much Easier to Operate," *Personal Computing*, August 1, 1989, Vol. 13, No. 8, pp. 103-108.

[24] See Norton and Bass (1987).

Figure 4.2: Speed Comparison of Intel Processors



Source: iCOMP Index (http://www.intel.com) 1995 and 1997

(DRAM), including the 4K, 16K, 64K, and 256 DRAM. DRAMs are computer components which provide random access memory.[25]

In Figure 4.4, I use data from InfoCorp for the 1981 to 1991 period to show how the rise in 286 CPU sales caused the sales of 8088/8086 CPUs to decline. I also show how the sales of 386 and 486 CPUs caused the 286 CPU sales to decline.[26] In Figure 4.5, I use data from the *Computer Industry Almanac* to show (on a market-share basis) how 486 sales cannibalized the 386 market and how successive chip sales thus followed closely the Norton and Bass overlapping generations model. Inspecting Figure 4.5 reveals that, by 1993, 386 CPU sales and 386-based computer systems had peaked and were declining significantly. Further, the prices for these systems and CPUs had also declined significantly. From various issues of *Byte* magazine, I have seen, for example, that the 386/33 MHz CPU sold for approximately $345 in 1989. By 1990, its price had fallen to $225, to $140 by 1992, and to $90 by 1993. Price declines also occurred in 486 CPUs and systems. In May 1991, a 486/33 MHz CPU sold for $1150. By October 1992, its price had declined by two-thirds, to approximately $340–$380.

In summary, I find that the market for 386 computers had peaked by 1991. While sales of SX-based systems (low-end, 16-bit interface processors) continued somewhat in 1992 and 1993, 386 DX sales were exhausted by 1993. I also observe that 486-based system sales were on the increase. These observations follow exactly the classical product lifecycle pattern. 486 system prices and CPU prices had their biggest price decline during 1990–1991 and 1991–1992.[27]

4.4. Limitations in the Royalty's Value

4.4.1. The Presence of Non-Infringing Substitutes Limits the Value of a Patent

Several non-infringing third-party upgrade solutions were available for consumers to purchase even if they did not purchase proprietary upgradeable systems from brand manufacturers. Cyrix provided an upgrade daughterboard, which utilized a single-socket upgrade design.[28] TransComputer offered a sim-

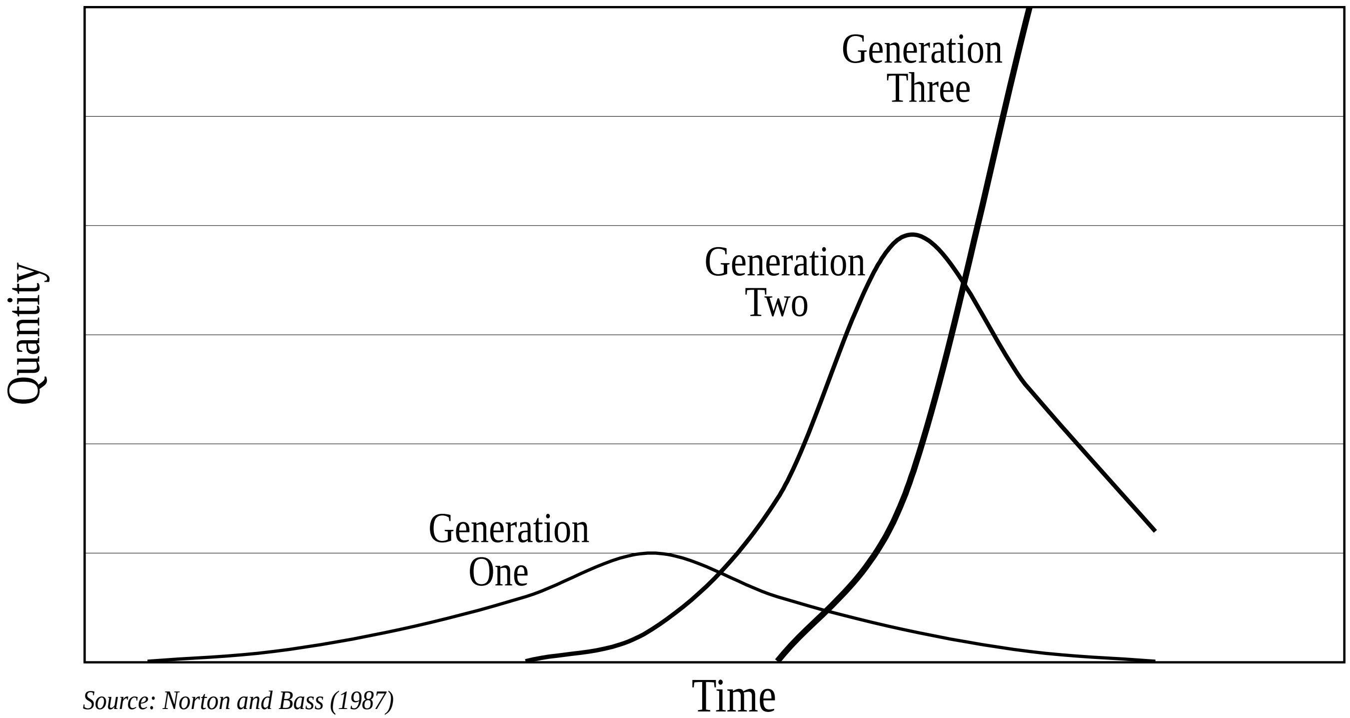
[25]I note that in terms of technological progress, circa 1987, the high-end DRAM technology contained 256,000 bytes of memory on a chip. The standard today is 128 megabytes per chip at similar lower unit cost.

[26]An example of the Pentium II processor eroding the markets for the Pentium Pro and Pentium MMX is given in *Intel Microprocessor Forecast*, *http://www.shipanalyst.com/techlib/intel/index.html*.

[27]For instance, motherboard prices with 486/33 MHz CPUs were approximately $2,095 in May 1991. These same motherboards were sold for $849 in May 1992 and for $499 in May 1993.

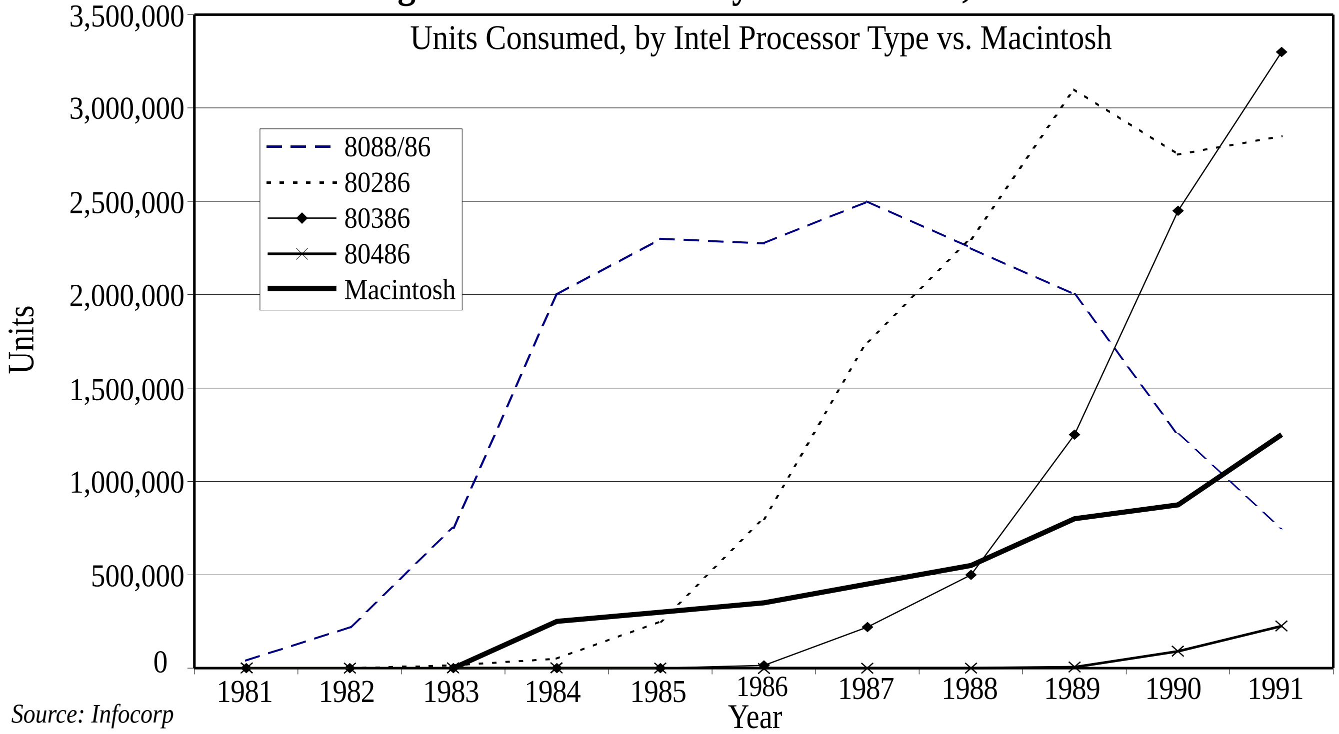
[28]*PC Magazine*, May 31, 1994, Vol. 13, No. 10, p. 52; *PC World*, May 1, 1992, Vol. 10, No. 5, p. 34.

Figure 4.3: A Series of Technological Changes



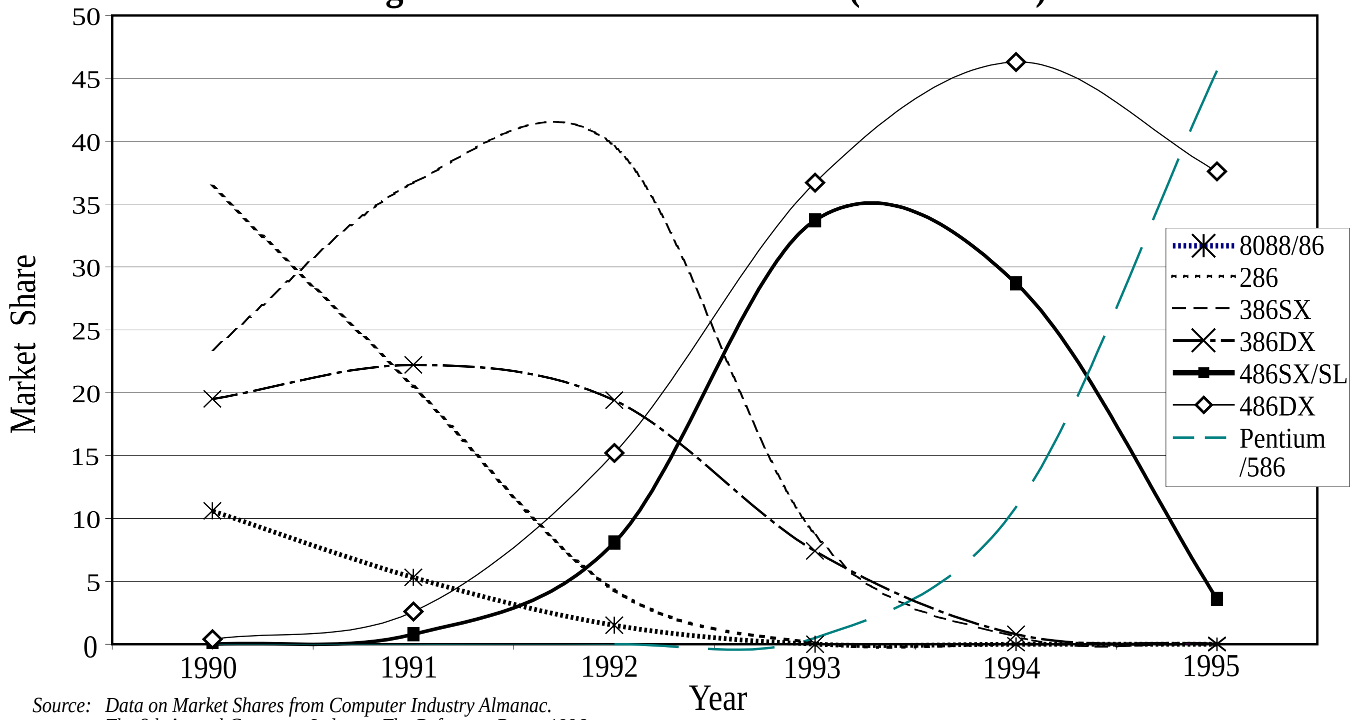
Source: Norton and Bass (1987)

Figure 4.4: U.S. Microsystems Market, 1981 - 1991



Source: Infocorp

Figure 4.5: CPU Market Share (1990 - 1995)



Source: Data on Market Shares from Computer Industry Almanac. The 8th Annual Computer Industry. The Reference Press. 1996 ilar product.[29] Evergreen Rev to 486,[30] MicroMaster 386/33,[31] 486/25 Power Platform[32] all provided aftermarket upgrades for the 386 system.

The presence of third-party products, which were of similar quality, as early as 1992 significantly crowded the upgrade market. Many competitors would lead consumers to elastically demand the dual-socket motherboard design. The presence of competition would have led to lower royalty rates.

4.4.2. The Value of a Consumer Upgrade Option

In this section, I analyze how consumers value an upgrade option.[33] This model shows that consumers will value the upgrade option greatest when the price of the next-generation processor is also at its peak. This is also the time when the next generation processor's price is expected to decline most. As the next generation processor's price declines, so does the value of the upgrade option.

The pricing model is based on a number of assumptions that reasonably describe how consumers value computer systems according to their performance. I assume in my model that the 386 processor has a speed of 1 unit (this is a normalization that is not consequential). Consumers can increase their computer's speed by switching to a processor in the 486 generation and receive a speed increase of γ percent. The system costs an amount \$C and the additional cost for the second socket (the upgrade option in the dual-socket design) costs \$S to the consumer. Finally, today's cost of a 486 chip will be denoted by P_0 and the cost in one year (the upgrade period) is $\tilde{P}_1$. (The symbol above the price P_1 denotes that P_1 is unknown at time period 0 and is treated as a random variable). I assume that the system cost includes a 386 CPU and that the 386 has little or no residual value in one year's time. Finally, I assume that a given consumer values speed in computers at the rate of \$$\lambda$ per unit of speed.

Different consumers will have different values, λ, leading some to purchase a 486 today rather than waiting. Other consumers will choose to wait to get a 486 via an upgrade. I now ask the question: "what is the maximum a consumer would value the second socket in the dual-socket before they would prefer to buy the 486 today rather than later?"

The value today for a risk-neutral consumer who upgrades in one year is:

[29] *PC Week*, June 18, 1990, Vol. 7, No. 24, p. 16.
[30] *PC Week*, November 8, 1994, Vol. 13, No. 19, p. 110-151.
[31] *PC World*, May 1, 1990, Vol. 8, No. 5, p. 88.
[32] *PC Week*, June 19, 1989, Vol. 6, No. 24, p.5.
[33] Similar models for replacement decisions in economics appear in Eckstein and Wolpin (1989).

$$V_u = \lambda + \lambda(1+\gamma) - C - S - \tilde{P}_1$$
$$= \lambda + \lambda(1+\gamma) - C - S + \tilde{r}P_0 - P_0$$

where $\tilde{r} = (\tilde{P}_0 - P_1)/P_0$ is rate of decline in 486 prices between year 0 and year 1. The value of upgrading is equal to the value of processing in the first year, λ, plus the value of processing in the second year at higher speed, $\lambda(1+\gamma)$, less the cost of system C, less the cost of the socket S, less the cost of the buying a new 486 chip at price $\tilde{P}_1$ in the second year.

The value of buying a 486 today is $V = 2\lambda\ (1+\gamma)\ -C\ -P_0$. It is equal to two years of value at the higher processor speed less the system cost and less the cost of buying a 486 today. I note that there is no socket cost if the consumer buys the 486 personal computer straight away.[34]

The maximum a consumer would pay to upgrade would equate these two values since if the consumer paid more for the socket, it would be better for that consumer to upgrade immediately. Therefore the price of the upgrade socket cannot exceed: $S \leq -\ \lambda\gamma + \tilde{r}\ P_0$. In words, this equation implies that consumers may pay more for the upgrade socket when the decline in prices $\tilde{r}$ is greatest between 486 chips today and next year. Consumers will pay less for the socket when the speed difference is larger because they will value the speed in the first year to a higher degree, *i.e.*, there is a greater opportunity cost of not using the faster processor.

Consumers who are averse to risk will pay less for the option due to the uncertainty in the rate of decline, $\tilde{r}$. This can be proven mathematically using a utility function $U(w)$, which is concave in the consumers' wealth level. The upgrade option has expected utility: $EU(W_0 + \tilde{Z})$ where W_0 is initial wealth and $\tilde{Z} = 2\lambda + \lambda\gamma - C + \tilde{r}P_0 - P_0 - S$.

Using a first-order Taylor-series expansion, expected utility is $U(W_0 + \bar{Z}) + 1/2U''(W_0 + \bar{Z})\sigma^2$. Hence, the consumer's expected utility is the utility at the mean wealth level plus a term that lowers expected utility by the randomness in $\tilde{Z}$ as measured by its variance σ^2. Comparative static analysis demonstrates that the maximum socket value S falls due to the uncertainty term σ^2. Additionally, a positive time of rate preference will make a consumer prefer the faster speeds today rather than next year and lead to lower socket value. Finally, the consumer who purchases a computer with an upgrade option may not exercise the option to upgrade if 486 prices have not declined enough in the second period. This further reduces the socket's value.

In sum, consumers value the upgrade option most when the prices of the next generation processor are highest and expected to fall the fastest. Based on the evidence of price declines in 486 CPUs reported in the previous section, I

[34]The salvage value (if any) from not purchasing the 386 CPU would further limit the socket value.

conclude that the upgrade socket would have some value to consumers in 1990 and 1991, lower value in 1992, and virtually no value by 1993. Since the values consumers place on the socket determine its usefulness as a product feature and thereafter determine the reasonable royalty paid by re-sellers, I conclude that royalties would be positive in 1991 and 1992 and would be zero or negligible for a dual-socket, upgrade system by 1993.

4.4.3. Trademark and Patent Valuation

There are several methods to value trademarks and patents. One method is known as the cost approach where the analyst attempts to estimate the cost involved in developing the patented item. In a second approach, termed the comparables approach, the analyst attempts to compare the item at issue to other similar items for which royalties have been established in the marketplace. In the market approach, the analyst analyzes the price premium or profitability of the item and then bases the royalty rate on a split of the profits between the licensor and the licensee to reflect the differential risks experienced by the manufacturer and the patent owner. Another related technique is known as the income approach where the analyst values the royalty based on the income stream produced by ownership of the patented item. Here, I rely on the comparables and market approaches to determine a reasonable royalty for the Acer patent.

First to establish a royalty rate based on comparables, I used the royalty rates in Smith (1997). Smith considers ranges of royalties by the licensee's use of various trademarks (whether pertaining to commercial/industrial products, consumer products and services, food and apparel, or toys/game/entertainment) and by the type of the trademark (whether institutional, corporate, fashion, celebrity, character, or college/sports). In establishing a reasonable royalty for the Acer patent, I used the commercial/industrial use for corporate type trademarks. The royalty values established by Smith (Smith, p. 178) are in the range of 0.5 to 1 percent (royalty rate relative to sales).[35]

The second method I discuss to establish a reasonable royalty is based on market transactions. Using advertisements by Atman, a manufacturer of motherboards that used a dual-socket upgrade, I analyzed the prices for motherboards in September 1992. Atman's motherboard with a 386/40 MHz CPU then sold for $200. Using *Byte* magazine, I determined that Intel 386/40 MHz CPU chips were selling for $80 to $100 at this time. At the same time, Atman offered the same motherboard with a 486/33 MHz CPU for $480. During this period, 486/33 MHz CPUs sold in the range of $340 to $380.

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[35] Arguably, the patent at issue would have a higher valuation than its trademark value but not exceedingly so given the availability of close substitutes.

Hence, I ascertained that the ATMAN motherboard was worth approximately \$100 to \$140 (the total price less the CPU cost).[36] This price is little different from the price that Acer sold its motherboards for in 1992. Furthermore, prices for the motherboard with 386 CPU imply a value of \$100 to \$120 together for the motherboard and the empty socket. Using M to represent the value of the motherboard and S to represent the value of the socket, it follows that \$100 $\leq$ M $\leq$ \$140 and \$100 $\leq$ M+S $\leq$ \$120, so that \$0 $\leq$ S $\leq$ \$20. Since both products are sold in market equilibrium, the socket has an implicit value between \$0 and \$20. I take the average value in this range of \$10. Furthermore, manufacturing is not free and involves an incremental cost of \$1 or more. Thus, incremental profits are no more than \$9.00 for the socket at retail. Assuming a retailer or dealer mark-up of approximately 33 percent implies that the profit to the manufacturer is about \$6.00. Of this amount, the licensee will typically receive 25 percent while the licensor will receive the remainder (Goldscheider's Rule). Hence, a patent owner might expect roughly \$1.50 from the sale of each motherboard. Using the 386 motherboard price with CPU as the denominator for calculation of the royalty percentage, the royalty rate would be approximately 0.75 percent. This figure is in the middle of range given by Smith (1997).

4.5. Conclusions

In the conclusion, I calculate Acer's lost royalties from possible patent infringement due to sales made by generic PC manufacturers. Even if generic manufacturers had licensed the "Chip-up" technology, the royalties would have been small given the degree of scope, duration, and royalty rates as we have seen.

Sales data for the top twenty computer manufacturers from 1990 through 1994 is presented in Table 4.2 and was derived from InfoCorp sources. Figure 4.6 presents the sales by manufacturer in 1991 based on the InfoCorp information.

From *Computer Industry Almanac*, I determined that approximately 58% of computer systems during this period were of 386SX or 386DX type. I apply this percentage to Acer's sales, and further assume that all units of 386 type would use the dual-socket design. Using the *InfoCorp* data for 1991 and 1992 sales, I determined that the collective non-top twenty, *i.e.*, no-brand PC sales were 2,437,521 units in 1991 and 2,865,853 units in 1992. I apply a fraction of fifty percent to sales in 1991 since the Acer patent would not have covered all of 1991. I do not include any sales for 1993 or beyond in the calculation

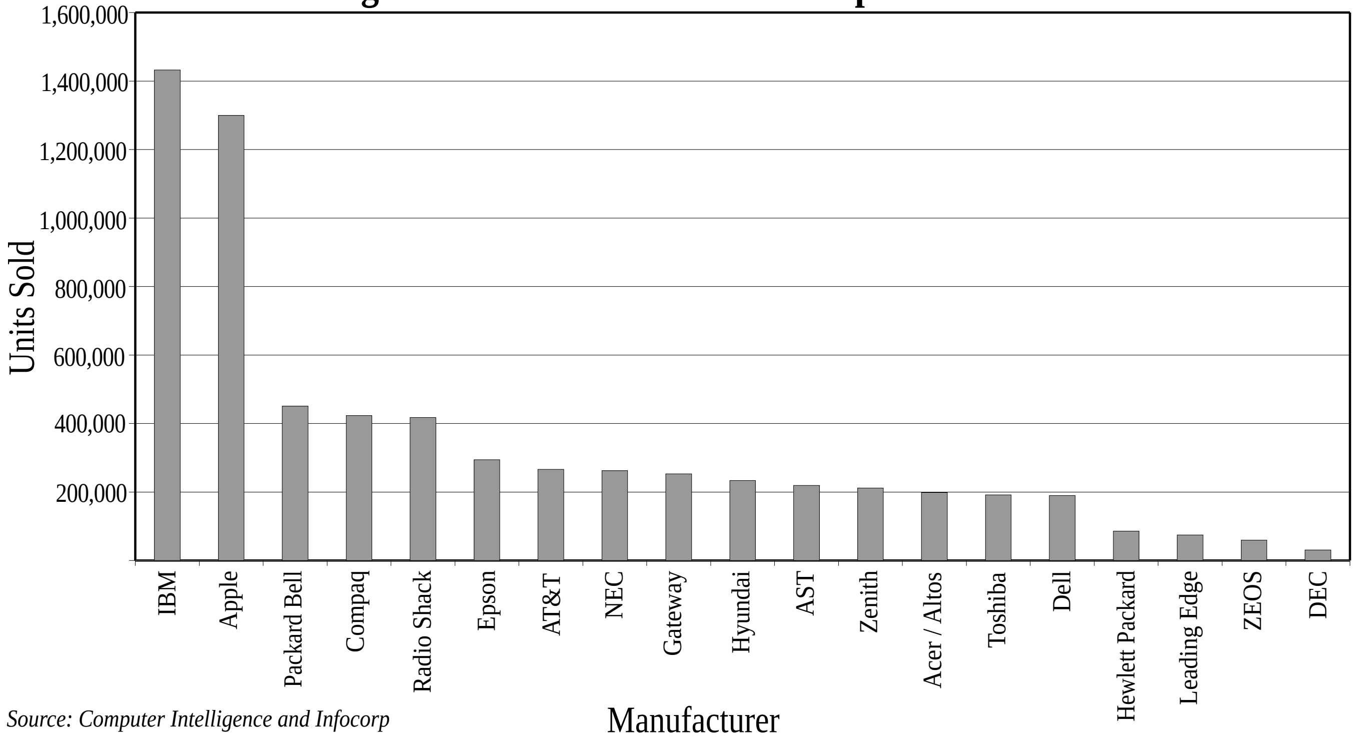
[36] In this comparison, there is a purposeful asymmetry. The 486 motherboard also contains the empty socket. But the socket is of no value to the consumer. The consumer will only upgrade and will never downgrade the motherboard.

Table 4.2. Top Twenty Computer Manufacturers

1994 Rank	Manufacturer	1990	1991	1992	1993	1994	1994 M.S.
1	Compaq	435,596	423,390	673,242	1,475,205	2,388,736	12.54%
2	Apple	945,086	1,299,398	1,433,287	1,946,291	2,226,736	11.69%
3	IBM	1,516,786	1,432,034	1,296,687	1,726,354	1,874,071	9.84%
4	Packard Bell	303,551	450,519	643,470	998,384	1,370,435	7.19%
5	Gateway 2000	102,000	253,103	659,890	749,369	1,118,982	5.87%
6	Dell	126,745	189,583	421,499	737,495	954,308	5.01%
7	Toshiba	185,008	191,671	206,421	309,489	533,016	2.80%
8	NEC	241,038	262,048	241,206	255,020	491,665	2.58%
9	AST Research	162,021	219,364	262,618	423,058	458,556	2.41%
10	Hewlett Packard	89,259	85,781	84,142	198,937	410,616	2.16%
11	DEC	32,872	30,774	50,543	174,150	322,763	1.69%
12	Acer/Altos	169,490	198,708	236,452	241,864	320,246	1.68%
13	AT&T GIS	218,884	266,251	255,816	271,891	315,507	1.66%
14	Epson	342,992	293,947	261,131	242,588	273,185	1.43%
15	Tandy/Radio Shack	487,637	417,302	403,650	309,814	258,418	1.36%
16	Zenith Data Systems	206,858	211,483	186,834	140,957	170,344	0.89%
17	ZEOS International	36,180	59,427	68,557	59,620	120,047	0.63%
18	Ambra/IBM	–	–	–	47,159	106,691	0.56%
19	Leading Edge	47,388	74,374	145,448	117,165	100,223	0.53%
20	Hyundai Electronics	203,735	233,793	221,459	161,387	93,832	0.49%
	Total (Top 20)	5,853,126	6,592,950	7,752,352	10,586,197	13,908,377	73.01%
	Total (All)	8,016,883	9,030,201	10,618,206	14,499,653	19,049,962	
	Residual	2,163,757	2,437,251	2,865,854	3,913,456	5,141,585	26.99%

Source: *Computer Intelligence* and *InfoCorp* as cited in *Brandweek* (March 20, 1995).

Figure 4.6: 1991 Unit Sales for Top Manufacturers



Source: Computer Intelligence and Infocorp of lost royalties for the reasons discussed above. Using half of 1991 sales and applying a percentage for the 386 machines at issue, I find that (1,218,761 + 2,865,852) * .58 = 2,369,076 units were in the 386 class. Based on my review of existing products in the relevant period, I find that only 5.5 percent of these 386 units would have used a dual-socket design. Therefore, royalties would be $1.50 * 2,369,076 * .055 = $195,449. I view the possibility of collecting this figure from third-party manufacturers as remote. Indeed, there is no evidence that Acer attempted to enforce their patent. The limited applicability of this particular patent and the availability of non-infringing substitutes to others constrained the value of the Chip-up technology.