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Intel and the x86 Architecture: A Legal Perspective

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ANTITRUST • COPYRIGHT • COMMENTARY

Intel, the [world's largest semiconductor manufacturer](#), owes its global leadership position to its x86 microprocessors. Intel and its main competitor, Advanced Micro Devices (AMD), command [80.4% and 11.5% of the microprocessor market](#), respectively. In other words, over 90% of the world's computers have brains that only understand the x86 instruction set for translating software instructions into computer functioning. Consequently, most computer programs support, if not exclusively, x86 microprocessors. The fact that AMD is their sole surviving competitor in the x86 microprocessor industry is testament to the success of Intel's aggressive business and legal tactics: the market for almost any other computer hardware component is certain to have a multitude of competitors from around the globe.

Throughout its history, Intel constantly has explored the outer frontiers of the high-tech industry's legal landscape as it asserted its market dominance, particularly when threatened by competition,

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and repeatedly has been forced to adjust its strategy when the courts found that it pushed too far. By zealously pursuing this strategy against AMD, Intel has kept AMD at a distant second place in the microprocessor market, despite AMD often offering superior products at lower prices. But Intel occasionally gets in trouble for its liberal use of business and legal force towards AMD. In the last two years, Intel saw the end to several high-profile antitrust cases that it had been tangled up in for years. In May 2009, [the European Commission fined Intel](#) a record 1.06 billion Euros for abusing its dominant market position. On November 12, 2009, [Intel settled](#) all outstanding antitrust and patent cross-licensing disputes with rival AMD for \$1.25 billion. And more recently in August 2010, [Intel settled its antitrust case with the FTC](#) by agreeing to [several broad restrictions](#) on its relationship with computer manufacturers and its competitors. But Intel's legal strategy of "trial and error" stems from the company's formative years, which coincided with the advent of the personal computer.

The Early Years: The Birth of x86 and the IBM PC

In the early 1980's, two of the computer industry's most influential pioneers were undergoing major transformation. Intel withdrew itself from the computer memory-chip industry and reinvented itself as a microprocessor manufacturer; and IBM made its foray into personal computers after years of denying the mainframe's inevitable death. IBM's PC development team [broke from the company's tradition](#) of developing complete solutions in-house by deciding to outsource most of the parts and components for its first model. At a time when the microprocessor market was still crowded with a panoply of competing architectures, IBM selected Intel's 8086 processor as the "brain" of its computer. However, IBM required that Intel find a second-source supplier because production had to be guaranteed and it was too risky to rely on a single company as the sole source of its chips. See Fred Warshofsky, *The Patent Wars: The Battle to Own the World's Technology* 134 (1994). Intel approached Advanced Micro Devices (AMD), a startup chipmaker that was [founded by fellow Fairchild Semiconductor alumni](#). The companies signed a technology exchange agreement in 1982, which the Ninth Circuit described as, "in effect a reciprocal second sourcing agreement: if one party

... direct, reciprocal, second-source requirement. If one party

wanted to market parts the other party had developed, it could offer parts that it had developed in exchange.” Intel Corp. v. Advanced Micro Devices, Inc., 12 F.3d 909, 910 (9th Cir. 1993).

The IBM PC was an enormous success. The IBM PC platform [captured a third of the personal computer market between 1981 and 1984](#), in part because of “IBM PC–Compatible” clones by manufacturers such as Compaq. IBM tolerated the clones because it was still nervous from the [antitrust lawsuit](#) that the DOJ had filed against it in 1969, which did not end until 1982. IBM created the PC platform in a way that allowed Intel and Microsoft, IBM’s licensors for the PC’s microprocessor and operating system, to sell those same parts to other computer manufacturers for use in their products. The only thing that was required to build a machine that was 100% compatible with the IBM PC was a reverse-engineered version of a chip in the PC called the BIOS ROM, which contains [low-level software used to interface between the hardware and the operating system](#). [Compaq first successfully developed such a chip in 1982](#), and Phoenix Technologies subsequently made one [available to all other clone manufacturers in 1984](#). [IBM’s goal](#) was to get as many players to participate in the market for personal computers as possible, and so it did not pursue any legal action against these reverse-engineered “clones”—preferring to compete on the merits of their version of the PC.

Intel abided by IBM’s second-source requirement as long as IBM was its main source of business. In accordance with their technology exchange agreement, Intel and AMD amended their contract in 1984 to allow AMD to be a second-source for the successive generations of the “x86” processor architecture (the successors to the 8086: the 80186 and 80286) in exchange for substantial royalties to Intel. Advanced Micro Devices, Inc. v. Intel Corp., 885 P.2d 994, 997–98 (Cal. 1994). But market conditions were changing. [By the end of 1986](#), IBM had lost control of the PC platform to the clone manufacturers. [More people were buying clones than were buying IBM PCs](#). Intel acted on this market trend: Compaq’s 1986 [Deskpro 386](#) was the first personal computer released with Intel’s [386 microprocessor](#). With IBM’s influence

declining and a ["gang"](#) of clone manufacturers eager to buy up their latest and greatest chips, Intel had little reason to continue adhering to the second-source agreement that had been mandated by IBM and, thereby, share its success with AMD.

Intel Breaks Up with AMD

As personal computer sales exploded, the different participants in the IBM PC ecosystem became uncomfortable with the alliances they previously had formed. IBM felt threatened by the clones' increased market power, and responded by surrounding their latest revision of the PC platform, the Micro Channel Architecture, [with high legal fences](#). Similarly, AMD threatened Intel when it released the Am286 in 1983, [offering twice the speed of Intel's 80286 at a lower price](#). Intel responded by trying to wall AMD out for the next generation of x86 processors.

Recognizing the phenomenal growth in the PC clone market, Intel saw an opportunity to exclude AMD and keep to itself the impending exponential increase in PC sales. Intel refused to consider any of AMD's products in exchange for rights to produce Intel's 80386 microprocessor, which was released in 1985. As a result, AMD claimed that Intel had breached their technology exchange contract, and petitioned for arbitration in 1987. The arbitration took four and a half years and included three hundred and fifty-five days of hearings. While the arbitrator found that Intel was not obligated to transfer every new product to AMD or accept any of AMD's products, he also decided that Intel had breached an implied covenant of good faith to make the relationship work. *Id.* at 1013. But this legal strategy paid off for Intel. By refusing to give AMD a license to the 386 and leaving the issue tied up in a lengthy arbitration, Intel excluded AMD during a critical period of growth in the personal computer market, during which the PC platform's market share [grew from 55% in 1986 to 84% in 1990; leaving Apple's Macintosh at a distant second place with just 6%](#). Without access to Intel's technical specifications, AMD took over five years to reverse-engineer the 80386, which was substantially more complicated than and contained almost [ten times as many transistors as the 8086](#).

Intel Sues Everyone for Everything

Intel did not stop at frustrating its agreement with AMD to defend its turf in the x86 processor industry; it began to pursue legal action against all threats to its market share. Intel had been actively

purging the microprocessor market of other manufacturers of x86-compatible processors. Intel had unleashed its legal arsenal on companies that did not have an x86 license and cloned Intel's chips through reverse engineering, alleging copyright and patent infringement. This expansive litigation activity from the late 1980s to the early 1990s marked the beginning of Intel's "trial and error" strategy: launch legal attacks against competitors, and when the courts gave Intel lemons, make lemonade by exploring alternative legal and business tactics to hinder the competition.

Just as the engineers at Phoenix Technologies had done with the BIOS ROM in the IBM PC, so Cyrix and NEC reverse-engineered Intel's x86 microprocessors using a ["clean room" design process](#) in which one team of engineers observed the chip's external, functional behavior and wrote technical specifications, and another team designed a functionally equivalent clone based on those specifications. The main purpose of the "clean room" approach was to avoid charges of illegally copying the reverse-engineered chip's design; the goal was to design a 100% compatible product without examining the contents of the chip. Instead of trying to argue against the "clean room" defense in a copyright action, Intel [sued Cyrix for patent infringement](#) in the United States District Court for the Eastern District of Texas. The district court ruled in favor of Cyrix, however, in 1992. It also engaged in what Cyrix termed a ["patent extortion scheme."](#) Intel held a patent for the technology on computer motherboards that linked x86 microprocessors with main memory, which Intel claimed covered any computer with an x86 chip. To stop computer manufacturers from using Cyrix's x86 clones, Intel threatened to demand a \$25-per-computer license fee for the memory controller patent should they switch microprocessor vendors from Intel to Cyrix.

Intel believed it had a stronger case for copyright infringement against NEC. A software engineer at NEC had studied the "microcode" of the Intel 8086 and 8088 microprocessors before

microcode of the Intel 8086 and 8088 microprocessors serves

the reverse-engineering process. This distinguishing fact made it unclear whether similar microcode found in the NEC's V20 and V30 chips was illegally copied from the 8086 and the 8088. *NEC Corp. v. Intel Corp.*, 10 U.S.P.Q.2d 1177, 1178 (N.D. Cal. 1989) ("A

microcode consists of a series of instructions that tell a microprocessor which of its thousands of transistors to actuate in order to perform the tasks directed by the macroinstruction set."). In 1989, [the Northern District of California found](#) that the microcode was copyrightable, but also found that it was possible to duplicate the functions of a chip without infringing on the copyright. The court ruled that NEC's microcode was sufficiently different from Intel's, such that it did not infringe. Despite losing to NEC, Intel remained optimistic about the ruling, as [it also meant that the 386's microcode was copyrighted](#). Intel hoped that copyright protection would stop AMD from releasing its version of the 386, the [Am386](#).

Accordingly, in 1991, Intel sought to enjoin AMD from releasing the Am386 in the Northern District of California based on the *NEC* case. *Intel v. AMD*, 12 F.3d at 911; *NEC*, 10 U.S.P.Q.2d at 1189. Intel reiterated its stance on its licensing agreement with AMD: "each proposed second-source agreement was to be the subject of combative bargaining with no continuing obligations from episode to episode." *AMD v. Intel*, 885 P.2d at 997. Intel sought an injunction against AMD's release of the Am386; however, any injunctive relief depended on the ongoing 1987 arbitration's outcome, since the arbitration would decide whether AMD should be awarded a license to the 80386. Because the district court was required to stay Intel's copyright action against AMD pending the outcome of Intel's appeal of the [1992 arbitration award](#) to the Superior Court of California, the Am386 effectively survived the injunction. *Intel v. AMD*, 12 F.3d at 910. The Am386 became a commercial success; not only was it faster than the Intel 80386 that it was based on, it was [almost as fast as Intel's newest 486 microprocessor but at a lower price](#). Desperate to keep the Am386 off the market, Intel even sued AMD for trademark infringement of the "386" name, but failed to prove that such a simple numerical combination was not generic. *Intel Corp. v. Advanced Micro Devices, Inc.*, 756 F.Supp.

1292, 1293 (N.D. Cal. 1991). Since deciding to go solo with the 80386 in 1985, Intel made it obvious that it would explore every last legal action available to keep AMD out of the x86 microprocessor business. When one litigation stalled or was lost, Intel simply sued

on different grounds in an attempt to exhaust AMD's legal resources.

Intel's legal battle with AMD became a perpetual drain on resources for both parties. By 1994, Intel had navigated the arbitration along its long journey up to the Supreme Court of California. The Supreme Court awarded AMD "a permanent, nonexclusive and royalty-free license to any Intel intellectual property embodied in the Am386" and "a two-year extension of certain patent and copyright licenses . . . related to the Am386." *AMD v. Intel*, 885 P.2d at 998–99. However, this result left several outstanding lawsuits unresolved, including [a 1991 antitrust suit](#) that AMD had brought against Intel in the U.S. District Court of the Northern District of California. The two companies had battled each other in court for seven years and had spent over \$100 million when [they finally settled all remaining lawsuits in 1995](#). AMD received a perpetual license to the microcode found in Intel's 386 and 486, but also [agreed to not copy any other Intel microcode](#). Instead, AMD would develop its own chips in the future.

Neither side was happy with this outcome. AMD had missed out on substantial profits during the Intel litigation. [AMD had a difficult time securing financing from lenders](#) to build new fabrication plants to keep up with demand. This physical plant handicap meant that AMD [struggled for years to keep up](#) with [Intel's multi-billion dollar investments in manufacturing facilities](#). On the other hand, Intel was forced to let AMD remain in the x86 microprocessor industry. AMD had proven [time](#) and [time](#) again to be a formidable opponent, [despite being a much smaller company](#). Furthermore, the computer industry had converged on the x86 architecture, based on the [number of computers using x86 microprocessors](#). Even an industry giant like Intel would not be able to force the computer industry to switch to [a new instruction set architecture](#) allowing it to abandon the x86 and AMD. Intel had no choice but to continue competing with AMD in order to maintain its leadership in

continue competing with AMD in order to maintain its leadership in the microprocessor market.

Intel Gets Sneaky

After settling all of its legal disputes with AMD in 1995, Intel had to compete on the merits of their products and encountered fierce competition from AMD. AMD frequently led Intel in introducing new technologies. AMD produced the world's [first x86 processor reaching 1 GHz](#), [64-bit x86 processor](#), [dual-core x86 processor](#), and [x86 processor with an integrated memory controller](#) (a major bottleneck if implemented as a separate chip on the motherboard, which Intel continued to do [until recently](#)). [AMD often beat Intel](#) in computer performance benchmarks. Accordingly, AMD gained significant market share in retail computer sales ([beating Intel with 52.5% of desktop PCs sold in U.S. retail stores for Q4 2005](#)) and in the lucrative server-chip market ([snagging 48% of the high-end multi-core server market in 2006](#); a market segment that Intel was still dominating in 2003). Intel therefore turned to other tactics to minimize AMD's gains in x86 market share.

Intel's most targeted approach to address its performance disadvantage was to provide software developers with [a compiler that would optimize their code to perform better on Intel microprocessors](#). In itself, the Intel compiler was a fair way for Intel to increase its products' computational performance: Intel was simply lending its resources to help developers squeeze more performance out of their programs. But Intel made the compiler compatible with AMD processors as well, thereby encouraging widespread adoption of its compiler and effectively planting [a Trojan horse](#) in the software industry. A common method to optimize code for a microprocessor is to exploit the microprocessor's performance-enhancing features and special instructions, called "extensions." Since the 1995 settlement, Intel had introduced [several extensions to the x86 instruction set](#) to expand its multimedia capabilities, of which many were [also supported by AMD](#). Naturally, if the Intel compiler was compatible with AMD microprocessors, one would expect it to take advantage of the multimedia extensions in any microprocessor that supported

them, be it Intel or AMD. However, Intel designed the compiler to first check the vendor ID found in a computer's microprocessor, and [only enabled the extensions if it was an Intel chip](#). Since many software vendors would compile their programs just once with the Intel compiler, their applications performed better on Intel chips,

but only because the multimedia features were artificially disabled for AMD chips. But AMD's performance lead was often too great to be overcome by compiler optimizations, and so Intel also turned to leveraging its immense bargaining power against computer manufacturers to maintain its leadership position.

Despite losing considerable market share to AMD, Intel held on to [a commanding lead](#) by exerting its influence on computer manufacturers. Most famous was the "Intel Inside" co-branding program, in which [Intel gave "market-development funds" to computer manufacturers if they highlighted the Intel brand on their products](#). But "Intel Inside" was not nearly as controversial as Intel's practice of paying "loyalty rebates" to computer manufacturers for not using AMD chips. On the surface, Intel's loyalty rebate programs appeared to be innocent volume or bundled discounts. Courts had struggled to apply section 2 of the Sherman Antitrust Act to the issue of bundled discounts, as it was [hard to distinguish harmless discounts from loyalty rebates](#) provided for the sole purpose of acquiring or maintaining monopoly power. But by taking into consideration the market conditions at the time and the nature of Intel's relationship with the computer manufacturers, the monopolistic intent underlying Intel's actions is noticeable. The [commoditization of the PC market](#) had severely impacted the profit margins of computer manufacturers, leaving their hopes of meeting quarterly earnings targets [at the mercy of Intel's loyalty rebates](#). In [internal emails](#) at major computer manufacturers, company executives were clearly distressed by the risk of losing such rebates, and most importantly, profitability, if they adopted AMD chips—or, as one Dell executive poignantly put it, Intel was ["prepared for 'jihad' if Dell joins the AMD exodus."](#) Indeed, AMD's biggest barrier in [breaking 25% in overall x86 market share](#) was its failure to court Dell, the biggest U.S. computer manufacturer. Dell was for a long time an exclusive Intel customer, but actually had been quite eager to use AMD's chips. [In an e-mail](#)

[to Intel's CEO in 2005, Michael Dell wrote](#), "None of the current benchmarks and reviews say that Intel based systems are better than AMD. We are losing the hearts, minds and wallets of our best customers." Intel was quick to address Dell's concerns. Intel's CEO, [Paul Otellini, replied](#), "[W]e are transferring over \$1B per year to Dell for meet comp efforts. This [should be] more than sufficient to compensate for the competitive issues." Soon after, [Dell's CEO Kevin Rollins](#) announced that Dell had "made no plans to begin using" AMD chips, which [Otellini described as](#) "the best friend money can buy."

But as AMD saw its market share [vanish inexplicably in certain markets](#), Intel attracted the attention of regulatory bodies worldwide. While trying to maintain its lead in the x86 processor market, Intel once again tried to test the legal boundaries with its aggressive business tactics, but ultimately wandered too far and faced competition law's wrath. [By launching its own antitrust lawsuit](#) and [scouring the world for regulators](#) who would agree to prosecute Intel, AMD succeeded in urging charges and fines against Intel from [Japan, Korea](#) and the [European Commission](#); as well as [antitrust charges from the FTC](#) and the [New York Attorney General](#). There was even a [SEC investigation](#) into the symbiotic relationship between Dell and Intel. The dollar amounts involved at the conclusion of the legal brouhaha surrounding Intel's anticompetitive pricing practices were astronomical: Intel was [fined 1.06 billion Euros by the European Commission](#) for abusing its dominant market position, and [settled its U.S. antitrust litigation with AMD for \\$1.25 billion](#). These rulings and settlements found many of Intel's actions to be illegal and prohibited Intel from continuing such practices. Intel's [settlement with the FTC](#) was the broadest resolution. Intel agreed not to use threats, bundled prices, or other offers to exclude or hamper the competition in the sale of microprocessors, and also to stop deceiving computer makers about the performance of non-Intel microprocessors through its compiler hacks. As a strategy to stave off and delay AMD's growth, however, Intel's tactics [left AMD in serious financial trouble](#) and even forced AMD to [spin off its manufacturing division in 2009](#). Moreover, Intel [recaptured the x86 performance crown in 2006 when it released the Core 2 Duo](#) microprocessor. Since then, AMD

has not been able to respond with a competitive product in the high performance, high profit margin market.

Intel and the Future of x86

The latest threat to Intel's dominance in the microprocessor market is the [shift towards tablet computers](#) like the Apple iPad. [Intel has already addressed market demands for low power devices by capitalizing on the netbook trend](#) from 2007 to 2009 with its power-efficient [Atom](#) processor, but netbook sales have suffered due to the [rising popularity of tablets](#). Having missed the first wave of tablet devices, Intel has [devised an attack plan](#) that will give it control over both hardware and the operating system and applications, in hopes of maintaining its market share in the microprocessor market as [PC microprocessor sales slow](#).

[Instead of relying on its long-time partner, Microsoft](#), Intel has followed its own software strategy in its entry into the tablet market. In February 2010, [Intel announced that it was partnering with Nokia to create a mobile operating system called MeeGo](#) to compete with Apple's iOS and Google's Android. As an open-source software project, MeeGo has garnered considerable support because of its [relative vendor neutrality](#). But to attract the [thousands of app developers from iOS and Android](#), MeeGo will need a better app store infrastructure than Nokia's Ovi, which [many developers have criticized](#). [Intel therefore announced its AppUp store at the Consumer Electronics Show](#) in January, and has since [signed on numerous retail partners, including Best Buy](#).

Intel has openly encouraged companies from across the computer industry, [including AMD](#), to participate in its tablet initiative. However, Intel's advocacy of the [Trusted Computing Initiative](#) and [recent acquisition of anti-virus software-maker, McAfee](#), has raised [concerns of vendor lock-in](#). Critics fear that building anti-virus functionality into the microprocessor will turn the computer market ecosystem into a "[walled garden](#)," requiring all software to come from a single source (AppUp) and be signed by a trusted authority (McAfee). The likelihood of such a scenario depends on whether [growing computer security concerns](#) will push computer users and the industry towards appliance-style devices meaning those with

the industry towards appliance-style devices, meaning those with functionalities entirely dictated by the manufacturer, and sacrifice “generativity”—as [Professor Zittrain has warned in his book, *The Future of the Internet and How to Stop It*](#). The closed, tethered [Apple iPad currently dominates the tablet market at 95% market](#)

[share](#). It is therefore likely that Intel can similarly appeal to consumers with an appliance-style device offering significantly superior computer security. But trusted computing remains a controversial proposal for solving computer security problems. [Critics have cited](#) risks of anticompetitive and anticonsumer behavior, as well as the risk that a trusted hardware manufacturer could secretly implement backdoor access to private user information. Even if it succeeded in locking out other vendors with its secure walled garden, Intel may find itself within the gray area of potentially anti-competitive product bundling. If the bundling is implemented such that most tablets are equipped with Intel processors and ship pre-installed with MeeGo and AppUp, and most software applications are only accessible through AppUp and must run on a trusted Intel platform, Intel will likely have to answer antitrust concerns similar to those that arose from [Microsoft’s bundling of the Internet Explorer browser with Windows](#).

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