SCIENCE BASED STANDARDS FOR THE UNIFORM GLOBAL PROTECTION OF INTELLECTUAL PROPERTY: THE CASE OF LOGIC FUNCTIONS EXPRESSIONS

INTRODUCTION

In an increasingly integrated global economy, worldwide protection of intellectual property rights has become a major consideration for U.S. businesses. In fact, it is a centerpiece of the United States' current international trade policy.[1] This policy is guided by the desire to enhance America's ability to compete in foreign markets by expanding opportunities for the global economy and insisting on similar responsibility from other countries.[2] To that end, any attempt to establish substantive standards for worldwide intellectual property protection requires international cooperation on trade systems reform[3] and emphasis on uniform adjustments of intellectual property laws to meet changes in technology—in particular, computer and semiconductor technology.

This Comment examines the necessary prerequisites for effective global protection of computer and semiconductor technology under a system of objective standards. Part I analyzes the current state of international intellectual property protection as offered by such multilateral trade treaties as GATT and NAFTA. It then addresses the conflict between national treatment and the concept of universal objective standards. Part I also proposes establishing international treaties that embrace a uniform intellectual property protection regime. Finally, it advocates international intellectual property protection agreements containing "objective criteria."

Part II considers whether the U.S. domestic system of copyright and patent protection of technology can become the model for a transnational regime. Computer and semiconductor technology protection reform is addressed in depth. To explain the need for such reform, this part demonstrates current problems presented by the highly dynamic computer and semiconductor technologies which require a new legislative and judicial approach to protection of expressive originality, one that will address computer and semiconductor technology issues within a single framework. It will be a *sui generis* computer and semiconductor technology protection regime.

A key precept of this regime is that the computer and semiconductor technologies landscape consists of an increasing diversity of functionally

1. Michael L. Doane, *Trips and International Intellectual Property Protection in an Age of Advancing Technology*, 9 AM. U. J. INT'L L. & POL'Y 465, 468 (1994).

2. *The Clinton Administration Trade Policy: An Update: Testimony by Michael Kantor, U.S. Trade Representative to the House Foreign Affairs Committee on U.S. Trade Policy*, 103d Cong., 2d Sess. (March 2, 1994) *available in* LEXIS, Legis library, CONGTST file.

3. *Id.*

discrete or hybrid constituents. Hardware[4] and software[5] are now functionally interchangeable[6] and they define a continuum within which other hybrid constituents rest. For example, logic functions expressions may occupy interim castes between hardware and software, between design notations and semiconductor layout design known as mask work, or between design notations and software. Therefore, hardware and software, once treated as discrete and insular intellectual property categories, can no longer be viewed as such, regardless of whether the proposed *sui generis* regime will be an offshoot of copyright law or a unique legal regime separate and apart from patent and copyright law.

Yet, it appears that this important precept has been ignored by the authors of *A Manifesto Concerning the Legal Protection of Computer Programs* which focuses on computer programs as distinguished from other industrial products.[7] Having addressed the principle concerns regarding computer programs protection,[8] for example, the inability of software developers to hold off rapid imitation by others, the authors contend that because programs are both literary works and machines, both copyright and patent law have had difficulties dealing with them.[9] As a result, the idea of a third general paradigm constructed for products inadequately protected by patent or copyright law has emerged.[10] By focusing on software protection alone, this alternative intellectual property regime leaves a fragmented protection system intact, contrary to the non-fragmented functional nature of the hardware-software spectrum.

To clarify this point, Part III offers a case study which demonstrates, *inter alia*, the use of objective standards to adjust current copyright laws in response to new forms of technology. In particular, the analysis focuses on copyrightability of logic functions expressions embodied in material objects

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4. Material objects are known as hardware.

5. Computer programs—literal and nonliteral elements alike—are known as software and are copyrightable. Computer Assocs. v. Altai, Inc., 982 F.2d 693, 701-02 (2d Cir. 1992). *See* Julian Valesco, *The Copyrightability of Nonliteral Elements of Computer Programs*, 94 COLUM. L. REV. 242 (1994).

This article proposes to broaden copyright protection beyond the literal and nonliteral elements of computer programs to other forms of expression whose character–software or hardware–is often ill-defined.

6. Zenatro Kitagawa, *Comment on a Manifesto Concerning the Legal Protection of Computer Programs*, 94 COLUM. L. REV. 2610, 2611 (1994).

7. Pamela Samuelson et al., *A Manifesto Concerning the Legal Protection of Computer Programs*, 94 COLUM. L. REV. 2308, 2332 (1994); Dennis S. Karjala, *Misappropriation as a Third Intellectual Property Paradigm*, 94 COLUM. L. REV. 2594, 2599 (1994).

8. Peter S. Menell, *The Challenges of Reforming Intellectual Property Protection for Computer Software*, 94 COLUM. L. REV. 2644 (1994); Richard R. Nelson, *Intellectual Property Protection for Cumulative System Technology*, 94 COLUM. L. REV. 2674 (1994); Jane C. Ginsburg, *Four Reasons and a Paradox: the Manifest Superiority of Copyright Over Sui Generis Protection of Computer Software*, 94 COLUM. L. REV. 2559 (1994).

9. Samuelson et al., *supra* note 7, at 2341; Nelson, *supra* note 8, at 2674; Ginsburg, *supra* note 8, at 2559.

10. Karjala, *supra* note 7, at 2594; Samuelson et al., *supra* note 7, at 2365 (advocating a market oriented approach); Kitagawa, *supra* note 6, at 2612.

known as integrated circuits.

Part IV concludes that a revised U.S. approach based on objective, universal, scientific standards, if adopted and enforced worldwide, could offer an effective uniform global protection of high technology.

The Appendix to this article contains an expansive description of computer and semiconductor chip technologies which is intended to provide a preview and foundation for the legal analysis that follows.

I. GLOBAL PROTECTION OF INTELLECTUAL PROPERTY

"The U.S. economy is now an integral part of the global economy. Over a quarter of the U.S. economy is dependent on trade."[11] As a major player in an increasingly integrated world economy, the United States has recognized that in order to preserve its status as the world's leading technological innovator it must pursue the reform of international trading systems.[12] Given that America's culture and technology are "prized around the globe,"[13] one major factor in that reform is a strong protection of intellectual property rights so that protection from infringement can reach beyond its borders.[14] Equally important is an adequate adaptation of these rights to the rapid evolution of high-technology-based industries.[15] The United States is a major producer and exporter of copyrighted materials, and estimated losses to U.S. industry from the woefully inadequate protection of such material from all forms of piracy and copyright infringement exceed $60 billion annually.[16]

For example, the semiconductor industry is a driving force for U.S. technological advances and competitiveness, and its products are incorporated in many of the goods traded internationally.[17] This and other high technology enterprises are a constant source of new technological concepts. Because science is universal and new technological concepts transcend national boundaries, U.S. creativity and innovation facilitate the evolution of competing high-technology-based industries worldwide.

The worldwide proliferation of computer technology and the growth of related industries underscores the need to define a proper scope of property rights in the products of this technology. The scope of such rights and, in turn, the level of their protection, affects the pace of innovation by influencing investment risk and economic incentives.[18]

It is hardly surprising, therefore, that negotiating bilaterally and multilaterally in order to obtain adequate intellectual protection worldwide

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11. Kantor, *supra* note 2.
12. *Id.*
13. *Id.*
14. *Id.*
15. Doane, *supra* note 1, at 465.
16. *Id.* at 466.
17. Kantor, *supra* note 2.
18. Doane, *supra* note 1, at 469.

involves adjusting international intellectual property law to meet changes in technology.[19]

A. Examination of Current Multilateral Trade Treaties

Mickey Kantor, the U.S. trade representative, declared that his principal responsibilities include "pursuing the strong protection of U.S. intellectual property, so important to our high technology industries."[20] With that in mind, U.S. representatives have engaged in a series of multilateral trade negotiations, one of which was the Uruguay Round of Negotiations of the General Agreement on Tariffs and Trade (GATT).[21]

In 1991, the persistence of the United States and other industrialized countries produced a proposed resolution mandating establishment of substantive standards for intellectual property protection.[22] This proposed resolution, known as the Trade-Related Aspects of Intellectual Property Rights, Including Trade in Counterfeit Goods (TRIPS),[23] required the establishment of mechanisms for enforcement of such rights.[24] To reach that goal, the governments and business communities of the United States, Japan, and the European Community, submitted proposals stating basic objectives and outlining specific substantive requirements for a TRIPS Agreement.[25] The United States proposed "to reduce distortions and impediments to legitimate trade in goods and services caused by deficient levels of protection and enforcement of intellectual property rights,"[26] by including basic standards for patents, copyrights and trademarks presently found in intellectual property laws of the United States.[27] The proposal also addressed computer programs and future computer technology copyright protection, to ensure that the development of a TRIPS agreement would take into account "new forms of technology and creativity as they appear."[28] Equally significant, the Japanese proposal expressed concern about protection of semiconductor devices.[29]

An agreement on TRIPS, one of the crowning achievements of the

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19. *Id.* at 468.

20. *Id.*

21. Final Act Embodying the Results of the Uruguay Round of Multilateral Trade Negotiations, Apr. 15, 1994, 33 I.L.M. 1125 (1994) [hereinafter Uruguay Round Final Act].

22. Doane, *supra* note 1, at 468.

23. Agreement on Trade-Related Aspects of Intellectual Property Rights, Including Trade in Counterfeit Goods, Dec. 15, 1993, 33 I.L.M. 81 (1994) [hereinafter GATT/TRIPS]. GATT/TRIPS is annexed to the Uruguay Round Final Act.

24. Doane, *supra* note 1, at 468.

25. *Id.* at 474.

26. *Id.* (citing *U.S. Framework Proposal to GATT Concerning Intellectual Property Rights,* 4 Int'l Trade Rep. (BNA) 1371 (Nov. 4, 1987) [hereinafter "U.S. Proposal to GATT"]).

27. Doane, *supra* note 1, at 474.

28. *Id.* at 475 (citing U.S. Proposal to GATT, at 1372).

29. *Id.* at 476.

Uruguay Round of GATT and the first multinational comprehensive agreement on intellectual property protection, was signed by 117 nations in Marrakech, Morocco, on April 15, 1994, concluding nearly eight years of negotiations.[30]

Under TRIPS, states parties must extend intellectual property protection to the nationals of other parties as if all parties had acceded to the various multilateral intellectual property conventions, such as: the Paris Convention on industrial property,[31] the Berne Convention on copyright,[32] the Rome Convention on sound recordings,[33] and the World Intellectual Property Organization's Washington Treaty on integrated circuits.[34]

TRIPS is only surpassed in its level of protection by the North American Free Trade Agreement (NAFTA)[35] between the United States, Canada and Mexico.[36] For example, TRIPS imposes no obligations to apply measures against "gray market"[37] goods.[38] Furthermore, NAFTA exceeded TRIPS in its interpretation of the Berne Convention to find an importation right, a public distribution right, and an expansive definition of "public" that broadens the Berne provision on communication to the public.[39]

TRIPS covers seven rights: (1) copyrights;[40] (2) trademarks;[41] (3) geographic indications;[42] (4) industrial designs;[43] (5) patents;[44] (6) layout-

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30. Richard E. Neff, *An IP Practitioner's Guide to GATT*, 2 INT'L COMPUTER LAW. 2 (1994).

31. GATT/TRIPS, art. 2. Paris Convention for the Protection of Industrial Property, Mar. 20, 1887 as revised at Stockholm on July 14, 1967, 21 U.S.T. 1583, 828 U.N.T.S. 305.

32. GATT/TRIPS, art. 9. Berne Convention for the Protection of Literary and Artistic Works, Sept. 9, 1886, as revised at Paris on July 24, 1971, and amended in 1979, S. TREATY DOC. No. 27, 99th Cong., 2d Sess. 1 (1985), 828 U.N.T.S. 221.

33. GATT/TRIPS, art. 2. Rome Convention for the Protection of Performers, Producers of Phonograms and Broadcasting Organisations, Oct. 26, 1961, 496 U.N.T.S. 43 (1964).

34. GATT/TRIPS, art. 35. Treaty on Intellectual Property in Respect of Integrated Circuits, May 26, 1989, 28 I.L.M. 1477 (1989). The Washington Treaty was the first international agreement to protect layout designs. Neff, *supra* note 30, at 3.

35. North American Free Trade Agreement, Dec. 8-17, 1992, U.S.-Can.-Mex., arts. 1701-1721, 32 I.L.M. 605, 670 (1995) [hereinafter NAFTA].

36. Neff, *supra* note 30, at 13 n.1.

37. A "gray market" is a market created by unauthorized importation of copies or phonorecords that were lawfully made in another country. CRAIG JOYCE ET AL., COPYRIGHT LAW § 7.04 (3d ed. 1994).

38. *Compare* GATT/TRIPS, art. 51 n.13 *with* NAFTA, art. 1705(2). *See* Neff, *supra* note 30, at 14, n.15.

39. NAFTA, art. 1705(2). *See* Neff, *supra* note 30, at 4. Under 17 U.S.C. § 106 the owner of the copyrighted work has exclusive distribution and performance rights. That is, the ability to control the transfer or display of physical copies of the copyrighted work, including the ability to control the first public distribution of authorized copies by sale, rent or otherwise. The owner of the physical copy cannot reproduce or perform the copyrighted work publicly (beyond his immediate circle of family and friends) without the copyright owner's permission. 17 U.S.C. § 101 (1976). *See* JOYCE, *supra* note 37, at 531-32.

40. GATT/TRIPS, arts. 9-14.

41. GATT/TRIPS, arts. 15-21.

42. GATT/TRIPS, arts. 22-24.

43. GATT/TRIPS, arts. 25-26.

designs of integrated circuits;[45] and (7) trade secrets.[46] The copyright provisions of the TRIPS agreement generally codify the traditional standards of the Berne Convention for the protection of literary and artistic work. Copyright protection is extended to nonliteral elements of literary works such as compilations of data and database, and to literary works such as computer software, with the goal that no special or *sui generis* system of protection should apply to computer programs.[47]

B. The Conflict Between National Treatment and the Concept of Universal Objective Standards

Problems arise when many nations read their national treatment obligations narrowly.[48] By creating what they consider to be new rights or subject matter and then asserting that their national treatment under copyright agreements does not extend to such new areas, many nations deny certain benefits to foreign nationals.[49] TRIPS falls short of NAFTA with regard to provisions on national treatment of copyright. Under TRIPS, any national exceptions to copyright protection are required to be narrowly drawn, not in conflict with normal exploitation of the work, and not unreasonably prejudicial to the right holder, much like Article 9(2) of the Berne Convention from which TRIPS derived its provision.[50] While NAFTA has identical language, it imposes tighter restrictions on compulsory licenses for translation and reproduction licenses as permitted under the Appendix to the Berne Convention.[51]

Substantive legal rights to any given subject matter are the products of negotiation and legislation. Conversely, the products of science and technology concepts embodied in a given subject matter are the products of non-negotiated, non-legislated laws of nature. Accordingly, any discriminatory national treatment of creative products that is disharmonious with an art or discipline involving science and technology is inconsistent with common sense and the art. Thus, objective standards can become useful measures to

44. GATT/TRIPS, arts. 27-34.

45. GATT/TRIPS, arts. 35-38.

46. GATT/TRIPS, art. 39.

47. GATT/TRIPS, art. 10.

48. Doane, *supra* note 1, at 481; Kantor, *supra* note 2 ("We were bitterly disappointed by the European Union's intransigence with respect to national treatment and market access.").

49. Doane gives the example of the European video levy system which collects and distributes funds to compensate copyright holders for private copying. While authors, performers, and video producers receive the levy funds, foreign video producers are denied their fair shares because video producers are not specifically covered by any agreement with a national treatment obligation. Consequently, American businesses with potential to generate substantial revenues from advances in technology stand to lose their fair share of revenues if the concept of the national treatment role is not modified. Doane, *supra* note 1, at 481-82.

50. GATT/TRIPS, art. 3. *See* Neff, *supra* note 30, at 5.

51. NAFTA, art. 1705(3); Neff, *supra* note 30, at 14 n.25.

eliminate discriminating national treatment of creative products, at least when the subject matter involves application of technology or science concepts, for such concepts are universal and transnational.

C. Objective Standards in Negotiated Treaties

"Behind proposed positions lie shared and compatible interests, as well as conflicting ones. . . . In many negotiations, . . . close examination of underlying interests will reveal the existence of many more interests that are shared or compatible"[52] and frequently, objective standards are useful in obtaining a resolution.[53] Seeking agreements containing "objective criteria" will result in "tangible progress."[54]

The rapid pace of technological evolution is only matched by the rate at which creativity and innovation are being exploited, often, without due regard to the rights of creators. One shared interest, no doubt, is the desire to reach mutually beneficial agreements on intellectual property protection of copyrighted or patented material involving high technology. In reaching that goal, the usefulness of objective, science-based standards is premised on the fact that science is universal. This common interest, therefore, provides the rationale for suggesting the use of objective, science-based standards during such treaty negotiations, because they can establish a negotiating range and provide the necessary foundation for legal arguments in favor of an effective intellectual property protection regime. Furthermore, science-based standards can support a minimum disposition below which no agreement can avoid running counter to established technology and science principles.

D. Proposing International Treaties that Embrace a Uniform Regime

The relevance of a pertinent technology is not frustrated by the fact that intellectual property protection is sought in many countries. On the contrary, it makes the application of uniform standards for determining or predicting intellectual property rights all the more critical. Uniform standards are much easier to define when the underlying theories are universal. Thus, standards existing in science and technology are prime candidates for uniform global treatment. These objective standards can be effectively used in subsequent bilateral and multilateral negotiations to bring about a uniform recognition that similar technologies must receive similar treatment without regard to the national origin of the copyrighted or patented work.

Because the industrialized nations recognize their common economic and political interest in developing some form of international property protection,

52. ROGER FISHER & WILLIAM URY, GETTING TO YES: NEGOTIATING AGREEMENT WITHOUT GIVING IN 42 (1991).

53. DONALD G. GIFFORD, LEGAL NEGOTIATION, THEORY AND APPLICATIONS 69 (1990).

54. Kantor, *supra* note 2.

and further recognize that: "trade [in] technology [products] constitutes a decisive pillar of the future competitiveness of research-oriented countries" adequate protection of the results of heavy investment in research and development is an absolute necessity.[55] The best way to protect this heavy investment is to ensure through negotiated agreements, that the results of research and development receive a treatment that is globally uniform and not dependent on national boundaries.

II. THE U.S. DOMESTIC PROTECTION OF INTELLECTUAL PROPERTY AS A FUTURE MODEL

Although the United States has a well established domestic system of intellectual property protection, many rapidly developing nations either lack such a system or fail to enforce it. Moreover, even if each country had its own intellectual property laws, there is inevitable frustration with enforcement predicated on local laws.[56] Hence, the benefits of a global uniform intellectual property protection regime become evident.

Can the U.S. domestic system constitute a future model for such a regime? It could, but before it may set the standards for other countries to follow, the U.S. intellectual property protection regime itself must undergo some fundamental adjustments so that it can provide meaningful protection for new forms of technology. Specifically, these adjustments must address current problems presented by the rapidly evolving computer and semiconductor technologies.

The first problem acknowledged by the courts is that "[g]enerally, [the courts] think that copyright . . . is not ideally suited to deal with the highly dynamic technology of computer science,"[57] and that "[t]hus far, many of the decisions in this area reflect the courts' attempt to fit the proverbial square peg in a round hole."[58] It follows that tenets of copyright and patent laws as well as the jurisprudential approach to interpreting technology issues must keep pace with the highly dynamic technologies.

The Supreme Court decision in *Feist Publications v. Rural Telephone*[59] gave rise to the second problem. "Confusion" is the best description of the state of post-*Feist* copyright protection.[60] Post-*Feist* copyright protects expressions, not facts.[61] Moreover, with the Supreme Court's renouncement

55. Ulrich Joos & Rainer Moufang, Report on the Second Ringberg Symposium, *GATT or WIPO? New Ways in the International Protection of Intellectual Property* 24 (Frederich-Karl Beier & Gerhard Schricker eds. 1989) (quoting Mr. Emory Simon).

56. Clark W. Lackert, *International Efforts Against Trademark Counterfeiting*, 1988 COLUM. BUS. L. REV 161, 162-63.

57. Computer Assoc. v. Altai, Inc., 982 F.2d 693, 712 (2d Cir. 1992).

58. *Id.*

59. Feist Publications, Inc. v. Rural Telephone Service Co., 499 U.S. 340 (1991).

60. Dennis S. Karjala, *Copyright in Electronic Maps*, 35 JURIMETRICS J. 395, 415 (1995).

61. *Feist*, 499 U.S. at 349.

of the "sweat of the brow" doctrine,[62] it has not been the objective of post-*Feist* copyright to reward the labor of authors or their investment of time or money. The *Feist* decision ignores the fact that courts have long recognized the economic underpinnings of copyright law.[63] While U.S. courts are struggling to avoid the strictures of *Feist* because they wish to protect costly and economically valuable products that are vulnerable to misappropriation, they are also bound to remain faithful to the *Feist* principle that maintains the relationship between the intellectual creativity standard and the scope of protection afforded by copyright.[64] The Fifth Circuit in *Kern River Gas Transmission Co. v. Coastal Corp.*[65] explained, for example, that "the guiding consideration in drawing the line . . . is the preservation of the balance between competition and protection reflected in the patent and copyright laws."[66] This suggests that there does not seem to be a reason for minimizing the economic implications of protecting costly, highly creative enterprises.[67] As a result, the tension among traditional copyright principles as they apply to electronically stored data "compilations," also known as electronic data-bases,[68] and other creative computer or semiconductor technology products has been heightened by the *Feist* decision because *Feist* leaves such desirable works without meaningful legal protection, even though they can be costly to create but cheaply and rapidly copied.[69]

Underscoring the economic value of copyright protection is the ephemeral nature of the state-of-the-art technology market place. As soon as a new technology is introduced, it is displaced by cheaper "clones"[70] or superseded by a superior technology. Hence, the race to achieve ample lead-time to capture the greatest market share and the need to obtain meaningful protection for all the hard-earned creative achievements are evident.

Unfortunately, patent law provides little or no resolution to the legal protection problem, because many creative works of authorship fail the novelty and non-obviousness tests of 35 U.S.C. §§ 102 and 103. Furthermore, protecting works by patents would, in some circumstances, confer a monopoly which, in contravention of public policy, may prevent others from utilizing universal design elements. Likewise, trade secret protection may be unavailing

62. The doctrine that rewards fruits of labor. *Id.*

63. Pamela Samuelson, *Counterpoint: An Entirely New Legal Regime Is Needed*, 12 THE COMPUTER LAWYER 12 (1995).

64. Karjala, *supra* note 60, at 415.

65. Kern River Gas Transmission Co. v. Coastal Corp., 899 F.2d 1458 (5th Cir. 1990), *cert. denied*, 111 S. Ct. 374 (1990).

66. *Id.* at 1463 (quoting Herbert Rosenthal Jewelry Corp. v. Kalpakian, 446 F.2d 738, 742 (9th Cir. 1971)).

67. Samuelson, *supra* note 63, at 13.

68. Karjala, *supra* note 60, at 396, 415.

69. *Id.* at 396, 398.

70. "Clones" are instruments or devices that imitate the original product by using authorized or unauthorized duplication of the original protected work, or by using a new design to duplicate the original idea(s).

when works can be reverse engineered.

Undoubtedly, as Dennis Karjala put it, "absent clarifying statutory amendment, courts are likely to discard the principle that copyright protection is coextensive with the expressive originality on which copyright is based."[71] Instead, the scope of protection afforded to a copyright-protected work will be determined through analysis of economic incentives, notwithstanding *Feist.*[72] In the long run, the courts' approach of separation between the expressive originality based copyright and the scope of protection may require either a statutory amendment to the definition of "compilations" and "literary works" under the Copyright Act or the adoption of a *sui generis* computer and semiconductor technology protection statute.[73]

Similarly notable, but apart from *the post-Feist* confusion, a conundrum that has bedeviled many efforts to analyze the software-hardware distinction as it relates to the distinction between copyrightable works and non-copyrightable material objects finds its source in the current statutory scheme with its separate computer programs and mask works protection. Consider, for example, logic functions expressions[74] which can be construed as products of computer as well as semiconductor technologies. Such expressions describe basic as well as complex logic operation, or alternatively, they describe the topology of digital circuits.[75] Logic functions can be reproduced on many types of material objects having different internal structures,[76] and their expressions will assume forms that vary with the type of device or medium in which they are embodied.

For instance, devices such as microprocessors are designed to execute a set of instructions selected from a fixed repertoire or vocabulary known as *microcode* or *op-code* which, when interpreted, produces an entry point to a corresponding *micro-routine* consisting of a unique set of logic and arithmetic operations. These operations are described via logic functions expressions that are then implemented in digital circuit blocks.

To translate their logic operations "ideas" into a target architecture format, digital circuit designers use many forms of logic functions expressions including schematic or graphic diagrams, tables, maps, hardware description text or computer files consisting of a "compilation" of high-level behavioral

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71. Karjala, *supra* note 60, at 395.

72. *Id.* at 395.

73. *Id.* at 398.

74. *See infra* Appendix Sections B-E for a comprehensive description.

75. Digital circuits consist of various logic 'gates' through which information in the form of electronic signals flows. Digital circuits are frequently used as building blocks of integrated circuits which, in turn, are grouped in families according to the specific set of functions they are intended to perform, e.g., discrete or user programmable logic devices, memory devices, microprocessors etc. Logic functions expressions, in whatever form, describe the relationships between signals coming in and signals coming out of such digital circuits, or in other words, the circuit topography through which the input signals pass on the way out.

76. 17 U.S.C. § 101 (1976). A "copy" is a material object in which work is fixed by any method. *Id.*

language statements. The process involves costly, and, in Pamela Samuelson's words, "highly creative and intellectually demanding enterprise."[77]

Typically, however, there has been confusion as to the eligibility of logic functions for copyright protection, notwithstanding that logic functions can be easily copied or reverse engineered, and that patent protection is frequently unavailable, thus, illustrating the above mentioned conundrum.

Given that the copyright discourse has largely emanated from the legal community, not from technology experts,[78] the focus on doctrinal analysis in many commentaries is key. For example, Christopher M. Mislow, writes in his article, *Computer Microcode: Testing the Limits of Software Copyrightability*, that the commonplace interpretation of the hardware-software distinction in the context of copyright law suggests that "Microcode is the lowest level of communication between the programmer and the computer, and where software ends and hardware begins."[79] Additionally, Michael Slater and Rich Belgard report in their article, *Intel Claims Am386 Infringes PLA Copyright*, that "there is no clear dividing line between hardware and software."[80] They ask, "Is the set of equations that defines the operation of a state machine software?"[81] They also doubt whether such equations, described in the form of high-level specifications, should be deemed software if they can be implemented in ROM or PLA.[82] Slater and Belgard conclude that if implemented in logic gates, this would be clearly hardware, and that using hardware description language in logic design does not make the hardware into (protectible) software expression.[83]

It is true that under current copyright law software ends at the microcode level.[84] It is also true that a mere description does not make hardware into software. Nonetheless, the above-quoted authors' conclusions are wrong. Simply stated, logic functions are necessarily neither software nor hardware, even though from the functional equivalence between programs and logic it follows that system operations can be performed, and, in turn, logic functions expressing them can be implemented by either hardware[85] or by software. In other words, logic function expressions occupy the interim space between

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77. Samuelson, *supra* note 63, at 13.

78. Samuelson, *supra* note 63, at 11.

79. Christopher M. Mislow, *Computer Microcode: Testing the Limits of Software Copyrightability*, 65 B.U.L. REV. 733, 738 (1985).

80. Michael Slater & Rich Belgard, *Intel Claims Am386 Infringes PLA Copyright: Lawsuit Attempts to Apply Software Copyright to PLA*, MICROPROCESSOR REPORT, Oct. 30, 1994, at 11, 12.

81. *Id. See* Appendix Section B for a definition of state machine.

82. *Id. See* Appendix Section B, for definitions of PLA and ROM.

83. Slater & Belgard, *supra* note 80, at 12.

84. *See* Mislow, *supra* note 79, at 738. "A computer program, whether in object code or source code, is protected from unauthorized copying under 17 U.S.C. § 102(a); if it is an original work of authorship fixed in a tangible medium of expression." *See, e.g.*, Allen-Myland, Inc. v. I.B.M. Corp., 746 F. Supp. 520, 531 (E.D. Pa. 1990).

85. Digital circuits capable of performing logic functions.

logic operations design "ideas" and their implementation in hardware or software. Alternatively, logic functions expressions that describe unique sets of logic operations performed during execution of microprocessors' microcode occupy the interim level between microcode expressions and their implementation in hardware.

Logic functions expressions can be implemented in hardware by being etched onto a semiconductor substrate,[86] by being "burned" in a memory device, or by being loaded to "configure" a user programmable device.[87] Alternatively, logic operations and, in turn, logic functions expressions can take the form of computer programs. Accordingly, logic functions expressions are neither hardware nor computer file copies though they can be "fixed" in such material objects,[88] where fixing is the final phase in the process of translating logic operations ideas into a target hardware configuration or software. The fact that logic functions expressions can be implemented in "logic gates" or, more generally, in integrated circuits, says nothing about their character as expressions before they are so embodied. Moreover, before logic functions expressions are etched on semiconductor substrates they must first be translated into a mask work.[89] Thus, the creative process of implementing logic operations ideas progresses through logic functions expressions to mask works and finally to hardware.

Notably, mask works are the last expression frontier which is afforded copyright protection under the *sui generis* Semiconductor Chip Protection Act of 1984.[90] Unlike mask works, computer programs have been expressly held to be subject to copyright as "literary works" of authorship.[91] However, there is a close link between computer programs and mask works because of

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86. 2 MELVILLE B. NIMMER, NIMMER ON COPYRIGHT § 8A.02[A] (1993).

87. "Configuration" of Programmable Logic Devices (PLDs) is analogous to "burning" of Programmable Read Only Memory (PROM). "Burning" means using electrical impulses to imprint each byte or word of information in a designated address by setting the corresponding cells to "ON" or "OFF" state. Similarly, impulses fed to PLDs join logic cells by setting to 'ON' interconnection paths.

88. Computer file copies are distinguished from their contents, i.e., computer programs which, in turn, also contain logic operations.

89.

> A mask work is a series of related images, . . . (A) having or representing the predetermined, three-dimensional pattern of metallic, insulating, or semiconductor material present or removed from the layers of a semiconductor chip product; and (B) in which series the relation of the images to one another is that each image has the pattern of the surface of one form of the semiconductor chip product.

17 U.S.C § 901(a)(2).

In other words, the logic functions are translated into a three layer image. Each image layer is a mask and is separately imprinted on a silicon (Si) crystal wafer that, among other things, is coated with a photoresistive emulsion and through the prescribed mask is selectively exposed to ultraviolet light. M.S. GHAUSI, ELECTRONIC DEVICES AND CIRCUITS, DISCRETE AND INTEGRATED 690-91, 702 (1985).

90. 17 U.S.C. §§ 901-914 (1987), *amended by* Pub. L. 102-563, 106 Stat. 4237, 4248 (1992).

91. Williams Electronics, Inc. v. Artic Int'l, Inc., 685 F.2d 870, 875 (3d Cir. 1982).

the functional equivalence between programs and logic, and due to the hardware-software interchangeability. In many instances, logic functions provide that link.

To a great extent, these two separate theories of protection, one for computer programs and one for mask works, are at the core of the hardware-software distinction conundrum. Additionally, this fragmented protection does not cover creative expressions of a class whose domain falls between computer programs and mask works. This protection gap leaves works such as logic functions expressions vulnerable to misappropriation by copying or reverse engineering. Therefore, these creative expressions cannot, and should not, be ignored by copyright law.

Inasmuch as computer programs and logic as well as semiconductor technology are so intertwined, and given that their protection has largely emanated from judicial interpretations of the Copyright Act, it follows that the question of logic functions or other expressions' copyrightability cannot be resolved within that framework without expanding the traditional limits of the Copyright Act by a statutory amendment to the definition of "literary works," or by adopting a *sui generis* statute for protection of expressive works related to computer and semiconductor technologies. The latter would be the better solution, doing away with separate protection for mask works and computer programs.

To that end, the Constitution clearly assigns Congress the task of defining the scope of the "limited monopoly" that should be granted to authors or inventors.[92] Indeed, Congress has repeatedly fashioned the law of copyright in response to significant changes in technology.[93] Meanwhile, the courts are struggling to resolve conflicts arising, to a large extent, from the Supreme Court's insistence that "sound policy, as well as history," mandates judicial deference to Congress as the forum best able to "accommodate fully the varied permutations of competing interests that are inevitably implicabled by such technology."[94] Thus in the absence of Congressional direction the courts are "circumspect in construing the scope of [copyrights]."[95] In taking this approach, however, the Second Circuit contends that the courts are all cognizant that computer technology is a dynamic field which can quickly outpace judicial decisionmaking.[96] This court has taken its own unique approach to the problem, which it contends "better addresses the practical difficulties [while] keep[ing] in mind the necessary balance between creative incentive and industrial competition."[97] This approach follows a tradition which Lord Mansfield promoted in a statement made two hundred years ago:

92. Sony Corp. of America v. Universal City Studios, Inc., 464 U.S. 417, 429 (1984).

93. *Id.* at 430.

94. *Id.* at 430.

95. *Id.* at 431.

96. Computer Assocs. v. Altai, Inc., 982 F.2d 693, 712 (2d Cir. 1992).

97. *Id.* at 696.

> [W]e must take care to guard against two extremes equally prejudicial; the one, that men of ability, who have employed their time for the service of the community, may not be deprived of their just merits, and the reward of their ingenuity and labor; the other, that the world may not be deprived of improvements, nor the progress of the arts be retarded.[98]

It follows that creative works which involve technological innovations should be encouraged and rewarded by securing for authors a fair return through a limited statutory copyright monopoly.[99]

It is also clear that, in the long run, the tension must be resolved between the two competing approaches, the first which recognizes the need to address the balance between creative incentive and industrial competition, and the second which gives deference to Congress and to Supreme Court decisions such as *Feist.* While it is hard to completely fault either approach, "honest application" of one or the other "would deny copyright protection to a variety of works whose optimal production, as a matter of social policy, may require some form of intellectual property right as an incentive," that is, a form of protection under some anti-misappropriation regime.[100]

By contrast, no fault can be attached to the adoption of a jurisprudential approach that calls for an application of objective standards[101] in interpreting technology issues. Likewise, Congressional review and reform of intellectual property laws would benefit from, and therefore should be based on, such objective standards.

III. CASE STUDY: THE USE OF OBJECTIVE STANDARDS TO REFORM COPYRIGHT LAW REGARDING SEMICONDUCTOR CHIP TECHNOLOGY

A way to illustrate the use of objective, science-based standards as a basis for reforming copyright law is the study of logic functions embodied in a prominent family of electronic devices capable of becoming "material objects in which a work is fixed" within the meaning of 17 U.S.C. § 101. This study will include an illustration of what constitutes a proper use of objective criteria existing in science and technology[102] in determining copyrightability of a subject matter, specifically, logic functions expressions embodied in integrated circuits.

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98. Twentieth Century Music Corp. v. Aiken, 422 U.S. 151, 156 n.6 (1975) (quoting Sayre v. Moore (1785), *reprinted in* Carry v. Longman, 102 Eng. Rep. 138, 139-40 n.(b) (1801)).

99. *Id.* at 156.

100. Karjala, *supra* note 60, at 396.

101. As stated before, objective standards are those existing in the science, art or technology which is employed to create the work in question.

102. The basic technology concepts that serve as objective standards are described, *infra*, Appendix, Sections A-E. Accordingly, if the reader is unfamiliar with computer and semiconductor chip technology, the following sections will be more meaningful if the Appendix is read first.

A. Do Logic Functions Whose Expressions are Embodied in Integrated Circuits Deserve Copyright Protection?

Congress has repeatedly fashioned the law of copyright in response to significant changes in technology. In fact, it may well be that Congress will take a fresh look at this new technology, just as it so often has examined other innovations in the past.

Arguably, since the rejection of the "sweat of the brow" doctrine by the *Feist* Court it has not been the objective of copyright to reward the labor of authors. It is undoubtedly true, however, that logic functions development often involves considerable expense and "highly creative and intellectually demanding enterprise." Moreover, "[g]iven that courts have long recognized the economic underpinnings of copyright law," there does not seem to be any reason for minimizing the economic implications of protecting logic functions expressions.[103] Accordingly, present copyright law provides the necessary and the only existing framework for logic functions protection, though it is not altogether well suited for the purpose or clear on this issue.[104]

But, given that copyright protection has largely emanated from judicial interpretation of the Copyright Act, the question of the copyrightability of logic functions expressions cannot be resolved within that framework without expanding traditional limits of the Act. Once again, objective standards provide the measures for overcoming such limits.

1. Constitutional Analysis

Article I, Section 8, clause 8 of the U.S. Constitution gives Congress the power "To Promote the Progress of Science and useful Arts" and provides the constitutional basis for federal intellectual property laws.[105] Specifically, that copyright protection may secure for a limited time to "Authors . . . the exclusive Right to their respective Writings."[106] The grant of limited copyright monopoly "is predicated upon the dual premises that the public benefits from creative activities of authors, and that the copyright monopoly is a necessary condition to the full realization of such creative activities."[107]

The most significant constitutional limitation in the Copyright Clause is contained in the word "writings," which indicates that only works which

103. Samuelson, *supra* note 63, at 12.

104. Patent protection will not do because such expressions will likely not pass the tests of novelty and non-obviousness of 35 U.S.C. §§ 102 and 103. Furthermore, contrary to public policy, patents would create a monopoly of logic design art. Likewise, trade secret protection is unavailing when works can be reverse engineered. Logic functions expressions are not to be confused with certain PLD semiconductor technology innovations that do receive patent protection.

105. U.S. CONST. art. I, § 8, cl. 8.

106. *Id.*

107. 1 NIMMER, *supra* note 86, § 1.03[A].

qualify as writings are protected under federal copyright statutes.[108] According to Nimmer, the basic rationale for the constitutional interpretation of "writings" was offered by Judge Learned Hand in *Reiss v. Nat'l Quotation Bureau*, where he stated that the constitutional grant "of power to Congress comprised not only what was then known, but what the ingenuity of men should devise thereafter."[109] Judge Hand also noted that "to be within the constitution the 'writing' must already have a meaning."[110] Thirty-seven years earlier, the Supreme Court had affirmed that "no one would now claim that the word 'writing' . . . is limited to the actual script of the author, and excludes books and all other printed matter."[111] These statements form the basis for constitutional interpretation of the term "writing," which is "given a content sufficient to encompass the artistic and technological developments of contemporary society."[112] Accordingly, writing may consist of non-verbal expressions including maps and charts, as well as works of pictorial, graphic and sculptural art.[113]

On what basis may one claim a copyright to logic functions expressions? Ironically, in *Feist*, Justice O'Connor provided the key to a resolution of this issue: "The writings which are to be protected are the fruits of intellectual labor" of authors to whom the writings owe their origin.[114] Originality remains the *sine qua non* of copyright,[115] where "[o]riginality is a constitutional requirement."[116] This requirement means independent creation of a work that possesses at least a "minimal degree of creativity,"[117] including creation involving original selection, arrangement and presentation of ideas, facts or non-original expressions.[118]

It is undeniable that logic functions expressions involve a creative process. Save direct copying, the logic functions development process involves numerous phases, not the least important of which is the "expression" phase. Each phase entails "highly creative and intellectually demanding enterprise." Skill and creativity propel such technological innovations toward new remarkable achievements. There can be no doubt, therefore, that logic functions expressions meet the constitutional requirement of creativity.

In order for a work to constitute a writing, however, it must also be embodied in some tangible material form, non-evanescent and capable of

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108. *Id.* § 1.08[A].

109. *Id.* (quoting Reiss v. Nat'l Quotation Bureau, 276 F. 717, 719 (S.D.N.Y. 1921)).

110. *Reiss,* 276 F. at 718.

111. Burrow-Giles Lithographic Co. v. Sarony, 111 U.S. 53, 58 (1884).

112. 1 NIMMER, *supra* note 86, § 1.08[A].

113. *Id.* § 1.08[B].

114. Feist Publications Inc. v. Rural Telephone Service Co., 499 U.S. 340, 346 (1991).

115. *Id.* at 348.

116. *Id.*

117. *Id.* at 345.

118. *Id.* at 348.

discernment.[119] Hence, logic functions expressions, to the extent that they are embodied in a tangible material, meet the two prerequisites of writing. Logic functions can be expressed in the form of a set of logic equations, Truth Tables, Karnaugh Maps, graphic design entry, text design entry, or waveform design representations. Whichever forms of expression logic functions assume, they are recorded on tangible materials consisting of paper, computer files, mask works, etc. This recording necessarily implies permanent, as opposed to ephemeral, material forms.

By reason of the Supreme Court's holding in *Goldstein v. California*, it is clear that a writing may be perceptible either visually or aurally.[120] It is further noted that, historically, the Copyright Act was amended to make it explicit that computer software, to the extent that it meets the prerequisites of a writing in that it embodies the author's original creation, is a proper subject matter for copyright.[121] It is proper subject matter, irrespective of the fact that software is not necessarily written down or recorded somewhere exactly as it is perceived by the human eye.[122] Similarly, mask works are regarded as a proper subject matter for which protection is available.[123]

The expression of logic functions is no different. Logic functions may be expressed in many forms that may or may not be recorded somewhere exactly as they are visually perceived. Since this fact did not deprive software expressions of copyright protection, it should not deprive logic functions of the same benefit.

2. Expanding the Traditional Limits of the Literary Works Definition

Copyright protects "original works of authorship" including *inter alia*, literary works.[124] Literary works are works "expressed in words, numbers, or other verbal or numerical symbols or indicia, regardless of the nature of the material objects in which they are embodied."[125] Labeling an original work, a "literary work" does not endow it with any literary merit or value.[126] Such works include instructional manuals, compilations of data, and computer programs, because they are expressed in words, numbers or other symbols.[127]

Logic functions expressions, such as logic equations sets, Truth Tables, behavioral design language text, or even design-description text fit nicely

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119. 1 NIMMER, *supra* note 86, § 1.08[C][2].

120. *Id.* (citing Goldstein v. California, 412 U.S. 546 (1973)).

121. 2 NIMMER, *supra* note 86, § 8.08[D].

122. Midway Mfg. Co. v. Artic Int'l, Inc., 547 F. Supp. 999, 1007, *aff'd*, 704 F.2d 1009 (7th Cir. 1982), *cert. denied*, 464 U.S. 823 (1983).

123. 17 U.S.C. § 902(b) (1984).

124. 17 U.S.C. § 102(a) (1976).

125. 17 U.S.C. § 101 (1976).

126. H.R. REP. NO. 1476, 94th Cong., 2d Sess., at 54 (1976).

127. Williams Electronics Inc. v. Artic Int'l, Inc., 685 F.2d 870, 875 (3d Cir. 1982).

within the above definitions of literary works. All of these expression forms are works expressed in words, numbers, or other verbal or numerical symbols or indicia, regardless of the nature of the material objects in which they are embodied. Therefore, logic functions possess no less of the characteristics of literary works because they are encrypted or devoid of literary merit.

Computer programs have been expressly held to be "works of authorship" subject to copyright.[128] The Copyright Act defines a computer program as "a set of statements or instructions to be used directly or indirectly in a computer in order to bring about a certain result."[129]

Analogously, logic functions expressions in the form of behavioral design language text are a set of instructions, shaped either as statements or as logic instructions, to be used in a computer in order to bring about the creation of PLD configuration file or an include file. Others, ROM-function-tables, for instance, are also forms of logic functions expressions that can be used indirectly in a computer to bring about a certain result. Hence, they can also be understood as copyrightable literary works of authorship.

The Supreme Court has already acknowledged the premise that, "[a]s a general matter, and to varying degrees, copyright protection extends beyond the strictly textual form of a literary work to its non-literal components, and it is essential that the right is not limited literally to the text, else a plagiarist would escape by immaterial variations."[130] For sure, the non-text forms of logic functions expressions must be also protected, so the present "literary works" definition is evidently not adequate because it is underinclusive or, plainly, not fitting the class of logic functions expressions.

3. Works of Utility and the Idea-Expression Dichotomy

The rights granted to a copyright owner under section 106 of the Copyright Act do not include the right to prevent others from using the copyrighted work.[131] Moreover, ordinarily a copyrighted work may be "used" by the public without infringing on the copyright owner's rights, notwithstanding the fact that copyright owners can prevent the use of their work by withholding access to copies of it.[132] There are, however, certain types of otherwise copyrightable works that may not be put to the use for which they have been designed without infringing the copyright owner's exclusive reproduction right; thus enforcement of this right may be said to conflict with the policy against restricting use of published works.[133] For "[w]here the truths of a science or the methods of an art are the common

128. *Id.*

129. 17 U.S.C. § 101 (1976).

130. Computer Assoc. v. Altai, Inc., 982 F.2d 693, 701 (2d Cir. 1992) (citing Nichols v. Universal Pictures Co., 45 F.2d 119 (2d Cir. 1930), *cert. denied*, 282 U.S. 902 (1931)).

131. 1 NIMMER, *supra* note 86, § 2.18[A].

132. *Id.*

133. *Id.* § 2-201.

property of the whole world, and [*sic*] author has the right to express the one, or explain and use the other, in his own way."[134] Accordingly, if enforcement of exclusive rights granted under the Copyright Act results in a monopoly of use not only to the copyrighted work itself, but also of the system, function or process of art, which connotes the "idea" upon which the work is based, does such enforcement become unavailing?[135] The Supreme Court in *Baker v. Selden*[136] answered this question affirmatively. There, protection was sought for original bookkeeping forms annexed to a book containing an introductory essay explaining the system of book-keeping.[137] The forms were useless unless they could be reproduced. In denying the grant of exclusive property right to make or use the bookkeeping forms, the Court reasoned that, although there is no doubt that a work on the subject of book-keeping may be copyrightable, "there is a clear distinction between the book, as such, and the art which it is intended to illustrate," and which anyone may practice.[138]

In so deciding, the Supreme Court laid the foundation for the "merger" doctrine and the issues surrounding the "idea-expression" dichotomy, expressed in *Kern River v. Coastal, Corp.*[139] There, the Fifth Circuit noted that "the Copyright Act reflects a tension created by Congress in balancing divergent public policies."[140] Most notably, the tension between section 102(a), which provides protection to original works of authorship, on one hand, and section 102(b) on the other hand, which provides that, "[i]n no case does copyright protection for an original work of authorship extend to any idea, procedure, process, system, method of operation, concept, principle or discovery, regardless of the form in which it is described, explained, illustrated, or embodied in such work."[141]

The *Kern River* court explained that the "guiding consideration in drawing the line [between an idea and its expression] is the preservation of the balance between competition and protection reflected in the patent and copyright laws."[142] The court explained that "[t]he doctrine of 'merger' [was] developed in an effort to deal with this difficulty in locating the precise boundary between idea and expression," and held that "when the expression of an idea is inseparable from the idea itself, the expression and the idea

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134. Baker v. Selden, 101 U.S. 99, 100 (1879).

135. 1 NIMMER, *supra* note 86, § 2.18[A].

136. 101 U.S. 99 (1879).

137. *Id.*

138. *Id.* at 102, 107.

139. Kern River Gas Transmission Co. v. Coastal Corp., 899 F.2d 1458 (5th Cir. 1990) *cert. denied*, 111 S. Ct. 374 (1990).

140. *Id.* at 1463.

141. 17. U.S.C. § 102(b).

142. *Kern River*, 899 F.2d at 1463 (citing Herbert Rosenthal Jewelry Corp. v. Kalpakian, 446 F.2d 738, 742 (9th Cir. 1971)).

merge."[143] It concluded that, "[w]hen the 'idea' and its 'expression' are thus inseparable, copying [using] the 'expression' will not be barred, since protecting the 'expression' in such circumstances would confer a monopoly of the 'idea' upon the copyright owner."[144]

4. The Utilitarian Nature of Logic Functions

The objective of determining which expressions are protectible can be accomplished by applying the same framework of analysis that is provided for computer programs. This approach is not unreasonable, given the general similarity[145] of (some) logic functions expressions to computer programs, the close functional relationships between logic functions and computer programs, and the utilitarian nature of both.

To determine the protectible elements of a computer program, the Second Circuit in *Computer Assoc. v. Altai* and the Tenth Circuit in *Gates Rubber v. Bando Chemical* adopted, in substantial part, the "Abstraction-Filtration-Comparison" test.[146] The first step in the analysis involves dissecting the program according to the abstraction test, breaking down the program and each of its modules in a way that parallels the typical development of a program.[147] Experts are called to provide guidance in ascertaining the six levels of generally declining abstractions of a computer program: (1) main purpose, (2) structure, (3) modules, (4) algorithms and data structures, (5) source code, and (6) object code.[148] Once the various levels of abstractions have been identified, those elements of the program that are not protected by copyright must be filtered out.[149]

To effectuate the purpose behind the copyright laws, the Second and Tenth Circuits applied the doctrines of merger and *scènes à faire* to filter out unprotected elements.[150] This approach will guide the analysis here. The endeavor of distinguishing between ideas and the expressions of those ideas must be necessarily ad hoc, given the varying nature of computer programs.[151] For example, the main purpose or function of a program will always be unprotectible idea, as opposed to the literal elements of the program which are always found to be protectible unless the doctrines of

143. *Id.*

144. *Id.* (citing Baker v. Selden, 101 U.S. at 103).

145. Some logic functions expressions take the form of high level code or machine code, much like computer software.

146. Computer Assocs. Int'l v. Altai, Inc., 982 F.2d 693, 696 (2d Cir. 1992); Gates Rubber Co. v. Bando Chem. Indus., 9 F.3d 823, 834 (10th Cir. 1993). The analysis here, however, is not concerned with comparison.

147. *Gates Rubber*, 9 F.3d at 834.

148. *Computer Assoc.*, 982 F.2d at 696; *Gates Rubber, 9 F.3d* at 835.

149. *Computer Assoc.*, 982 F.2d at 704; *Gates Rubber*, 9 F.3d at 836.

150. *Id.*

151. *Id.*

merger and *scènes à faire* come into play.[152]

By comparison, the distinction between logic functions design ideas and the expressions of those ideas, involves a review of the design process. Here again, experts can provide guidance in ascertaining the five or more phases of logic functions development: (1) design "idea," (2) design "expression," (3) design verification, (4) system integration, and (5) production. Once identified, works of authorship created during the "expression phase" must undergo the scrutiny of the merger doctrine, the doctrine of *scènes à faire,* and finally the public domain test.

As explained in the Appendix, logic operations are defined in terms of basic or universal operations: OR, AND, NOT, NOR and NAND. More complex functions can consist of blocks or arrays of these universal operations. Thus, such functions can be diversely expressed. Moreover, it was demonstrated that logic functions describing PLD configurations, ROM-functions-tables, and microprocessor microroutines and control functions, can be expressed and implemented in a variety of ways. Even labels of variables and functions can vary. Simple, basic, and short expressions, no doubt, leave little if any room for creativity. But, when designs consist of numerous variables and do not consist solely of basic or universal functions (single or multiple), or a set of duplicates thereof, then affording copyright protection is not granting a monopoly on "ideas."

Although it is the idea-expression distinction that has received primary attention, the Copyright Act also denies protection to purely utilitarian works.[153] When considering utilitarian works such as computer programs one of the most important elements is process.[154] "Although processes themselves are not copyrightable, an author's description of that process, so long as it incorporates some originality, may be protectible."[155]

Returning then to logic functions expressions, it is noted that, to the extent that they represent digital circuits functions, they describe the process of input variables traversing through logic blocks toward the outputs.

152. *Id.* Copyright may be claimed only in the "expression" of a work of authorship not its "idea." When an idea and it expression are inseparable the merger doctrine is applied to bar copyright protection. Kern River Gas Transmission Co. v. Coastal Corp., 899 F.2d 1458, 1463 (5th Cir. 1990), *cert. denied,* 111 S. Ct. 374 (1990).

In the process of filtering unprotectible elements of software, detailed examination of a computer program's components is made to determine whether their particular inclusion at each abstraction level was "idea" or was directed by considerations of efficiency so as to be incidental to that idea (and thus "merged" with it); required by factors external to the problem itself; or taken from the public domain, hence unprotectible expressions. *Computer Assocs.*, 982 F.2d at 707.

Under the *scènes à faire* doctrine, expressions employing certain 'stock' or standard literary devices, or standard techniques or design choices, are not copyrightable. *Computer Assocs.*, 982 F.2d at 709. In other words, incidents, characters or settings which are, as a practical matter, indispensable or standard in the treatment of a given topic are considered inherent in the work and not copyrightable. BLACK'S LAW DICTIONARY 800 (6th ed. 1991).

153. 1 NIMMER, *supra* note 86, § 2.03[D].

154. *Gates Rubber,* 9 F.3d at 837.

155. *Id.*

Likewise, they describe output-input relationships. This applies regardless of whether such expressions are in graphic form, text form, or wave form (graphic). But, the author's description is, as stated above, not barred from copyright protection.

Under the *scènes à faire* doctrine, protection is denied to those expressions that are incidents of ideas and that are "standard, stock or common to a particular topic or that necessarily follow from a common theme or setting," because such expressions lack the originality that is the *sine qua non* for copyright protection.[156] "The *scènes à faire* doctrine also excludes from protection those elements of program that have been dictated by external factors" such as hardware and software manufacture and design standards, and compatibility requirements.[157]

Accordingly, logic functions expressions whose contents and order are dictated by such external factors may be denied protection. Much depends on the magnitude of such expressions as compared with the level and nature of external factors' dominance. Simple logic expressions whose design is dictated by external controls and efficiency considerations are not likely candidates for copyright protection. In contrast, if a circuit is complex and external controls play only a small role in what is otherwise an extensive design, expressions thus created deserve protection.

It is important to note that certain labels of function variables are common terms of art. For example, CLK stands for clock, GND stands for ground, Vcc stands for power, I/O stands for input-output, D0 . . . D8 stand for data lines, ADD0 . . . ADD15 stand for address lines, etc. "The copyright of a work on mathematical science cannot give the author an exclusive right to the methods of operation which he propounds, or to the diagrams which he employs to explain them, so as to prevent an engineer from using them whenever occasion requires."[158] It is likewise obvious that expressions that use function variables in their intended industry usage, without more, cannot claim protection because no one should be barred from using common terms of art. However, if expressions contain original creations in addition to or in spite of using common terms of art, such expressions should not be denied protection.

Originality in the field of copyright requires that the work be "independently created" and "possess a minimal degree of creativity."[159] Accordingly works found in public domain are unoriginal.[160] This would apply to logic functions as well. Expressions consisting solely of design library extractions cannot claim protection, unless the functions or equations compilation is sufficiently original to qualify them for protection. The same is true for basic

156. *Id.* at 838.

157. *Id.*

158. Computer Assoc. v. Altai, Inc., 982 F.2d 693, 704 (2d Cir. 1992).

159. *Gates Rubber*, 9 F.3d at 837.

160. *Id.*

or universal logic expressions.

Once logic functions expressions are found to consist of more than merely ideas and unoriginal elements, such expressions have met the fundamental criteria for copyright protection. Thus, such expressions deserve to be endowed with the attribute of copyrightable subject matter.

CONCLUSION

The grant of limited copyright monopoly is predicated upon the dual premises that the public benefits from creative activities of authors, and that the copyright monopoly is a necessary condition to the full realization of such creative activities.[161] Given the costly, highly creative and intellectually demanding enterprise of high technology development, it appears that "to appropriate and use for profit, knowledge and ideas produced by other [people] without compensation or even acknowledgement may be inconsistent with a finer sense of propriety."[162] But the principle that condemns such appropriation also condemns the public to ignorance of the truths of science or methods of the art. "The noblest of human productions—knowledge, truths ascertained, conceptions and ideas—become, after voluntary communication to others, free as the air to common use."[163] After such communication, however, the intellectual property attribute of productions which involve creation, invention, or discovery should nonetheless continue.[164] Their attribute is demanded by public policy and at the same time it is affected by public interest, thus, it should afford only a qualified exclusion right.[165] The basic policy issue is a question of how strong an infusion of the private right of exclusion is necessary to refine the flavor of such a property attribute. Intellectual property law protection based on objective standards provides the best balance for the many interests at stake.

To ensure protection for state-of-the-art technologies such as computer and semiconductor technologies, it is imperative that U.S. copyright and patent laws undergo legislative reform so that they can keep pace with new forms of these technologies. To that end, Congress will have to construct a new framework which, at best, will be a forward-looking, *sui generis* protection regime capable of providing effective protection for computer and semiconductor technology products. Moreover, this regime will be best suited to deal with the peculiarities of computer and semiconductor technology when it recognizes the so-called hardware-software functional continuum.

Ideally, if the United States' revised approach were adopted and enforced worldwide through international trade treaties that embrace a uniform

161. 1 NIMMER, *supra* note 86, § 1.03[A].

162. Int'l News Serv. v. Assoc. Press, 248 U.S. 215, 257 (1918) (Brandeis, J., dissenting).

163. *Id.* at 225.

164. *Id.* at 215.

165. *Id.* at 225.

protection regime containing universal, objective standards, more meaningful technology protection would uniformly transcend international borders. Useful in the meantime is a vigilant adherence to the principle that any discriminatory national treatment of creative work products that is disharmonious with a discipline involving objective standards such as science and technology, is inconsistent with common sense and the art. Only if these objective standards are in place can a global intellectual property regime ensure uniform protection of high technology and the extensive investments of labor and capital required to create it. Finally, international trade systems reform that allows for adjustments of intellectual property right in products of high technology encourages undertaking the risks of heavy investment in research and development. However, the trade of technology products can be equitable only when international treaties are equitable and honored by member nations.

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APPENDIX: COMPUTER AND SEMICONDUCTOR CHIP TECHNOLOGY REVIEW

A. Noteworthy Developments

Computer technology touches every segment of modern society and it has become a major force in the world's economy. But much of what we take for granted in present-day technological development could not have been accomplished without the contributions of pioneer designs such as the 1940's Eniac, the first electronic computer[166] that led to the genesis of computer technology. Work on the Eniac attracted the attention of the mathematician and logic theorist, J. Von Neumann, who collaborated on a 1946 report titled *Preliminary Discussion of the Logical Design of an Electronic Computing Instrument.*[167] This report advanced a number of basic ideas, one of which is the notion of "stored program"—a set of arithmetic and logic instructions selected from a fixed repertoire or vocabulary.[168] This concept initiated a growing pattern of recognition of software in the effective utilization of computers.

No less revolutionary was W. Shockly's 1948 discovery of the *transistor.* Transistors, consisting of a three-layer silicon crystal called semiconductor, represent a class of components whose operation depends on the properties of matter in its solid state,[169] hence the term "solid state." Thereafter, *integrated circuits* were invented. This class of solid state devices consisting of multiple transistor circuits, also known as *semiconductor chips*, helped shape the future of modern technology as we know it today.

The development of solid state devices made possible the development of large capacity and fast computers. But the subsequent advent of microprocessors and microcontrollers gave rise to microcomputers and minicomputers which, for the most part, displaced the mainframe computers. With each increase in components' processing power, speed and storage capacity, new classes of technology problems became solvable. For example, as new families of integrated circuits capable of performing greater numbers of functions[170] were becoming commonplace, so was incorporation of microcontrollers, microprocessors and peripheral devices in instruments known as embedded systems, thus expanding their use beyond computers.

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166. Designed by Eckert and Mauchly, the Eniac used the vacuum tube as a digital computer component to perform the switching function of a relay (between two states, on/off) but at electronic speed. The Eniac (Electronic Numerical Integrator and Calculator), was conceived and built to produce ballistic (firing projectile) tables for the U.S. Army Ordnance Department. R. WADE COLE, INTRODUCTION TO COMPUTING 25 (1969).

167. *Id.* at 27.

168. *Id.*

169. *Id.* at 30, 31.

170. Integrated circuits are grouped in families according to the specific set of functions they are intended to perform. For example, discrete or programmable logic devices, memory devices, microprocessors, etc.

B. Basic Concepts of Logic Theory and Logic Functions Design

The electronic design theory which incorporates switching devices designed to perform logic functions is commonly known as *digital design* and the circuits containing such devices are collectively called *digital circuits*. Digital circuits perform basic as well as complex logic operations and they are used as the building blocks of integrated circuits.

The fundamental requirement of electronic circuits used for digital operation[171] is that the electrical variables (voltage, current) that represent information be discrete, taking only two values.[172] In most present digital machines the numbers are represented and the arithmetic operations are performed in a binary number system which uses two symbols, '0' and '1,'[173] where each binary number is a combination of one or more binary digits.[174] The two symbols represent the two possible states of a switching device.[175] The linchpin of digital design is switching algebra, introduced as a basic tool in dealing with problems encountered in the study of switching circuits, the basic building blocks of digital circuits. The basic postulate of switching algebra is the existence of two-valued switching variables which can take any two distinct values, 0 or 1, also referred to as *truth values*.[176]

Switching functions expressions consist of a combination of one or more of the basic logic operations (performed on switching variable(s)). Switching functions can be expressed by means of *logic equations*, *Truth Tables*, or a map method called *Karnaugh Map*. A logic equation expression representing a switching function consists of the *sum of product-terms* that correspond to those variable-combinations for which the function assumes the value 1. Each term is a product of the variables on whose values-combination the function depends.

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171. Digital operations are akin to discrete states transition (e.g., switching on/off) operations, as opposed to analog operations which are akin to smooth or linear operations whose range is limited by cut-off (inoperation) at the low end, and by saturation at the high end.

172. GHAUSI, *supra* note 89, at 594.

173. The role played by 0 and 1 in a binary number system is the same as that played by 0, 1, 2 . . .9 in the decimal system which uses the base 10. The binary system uses base 2, thus, only two numbers, 0 and 1, are used. For example:

$$(1001)2 = 1x2^3 + 0x2^2 + 0x2^1 + 1x2^{\cdot} = (9)10.$$

174. Strings of 1 and 0 digits compose binary numbers which, in computer technology context, correspond to *binary codes* representing computer program instruction codes, or to sets of digital machine states (including the set of: input signals, resulting output signals, internal machine state etc., also known as *switching variables set*). Frequently, these codes or sets consist of groups of 4 digits (known as *nibbles*), 8 digits (*bytes*), 16 digits (*double-bytes, or words*) etc. Each binary digit is also commonly known as a *bit*.

175. The two states of a switching device have no inherent values; each of them is, in reality, a voltage level, high or low, capable of being interpreted in any fashion we choose to assign to it. Instead of 1s and 0s, one could just as well use "ON" and "OFF," "HIGH" and "LOW," "TRUE" or "FALSE" or any other two-valued code. *See* Mislow, *supra* note 78, at 742.

176. ZVI KOHAVI, SWITCHING AND FINITE AUTOMATA THEORY 42 (1970).

For example,

$$f(x,y,z) = x'y'z' + x'yz' + x'yz + xyz' + xyz.$$

A switching function can also be expressed as a canonical *product-of-sums*. That is, those combinations for which the function is to have the value 0.[177] For example,

$$f(x,y,z) = (x+y+z')(x'+y+z)(x'y+z').$$

The following table lists basic functions of two variables:[178]

f (x,y)	Function Name	Symbol	Description
x'	NOT	x'	**NOT**—Complementation or inversion: 0' = 1; 1' = 0.
x y	AND	x • y	**AND**—Only if both, x <u>AND</u> y assume the value 1, x AND y equals 1, else it equals 0.
x + y	OR	x + y	**OR**—If either x <u>OR</u> y, or both, assume the value 1, x OR y equals 1.
(x + y)' ; or x'y'	NOR	x ↓ y	**NOR**—not OR
(xy)' ; or x' + y'	NAND	x | y	**NAND**—not AND
x'y + xy'	XOR	x ⊕ y	**XOR**—exclusive OR
x' + y ; x + y'	Implication	x → y ; y → x	

177. *See id.* at 51, 52.
178. *Id.* at 56.

The three basic logic operations are OR, AND, and NOT. Other, more complex, logic operations are defined in terms of these basic operations.

A switching circuit consists of *gates* through which information in the form of electric signals flows. A gate is a two-state device capable of switching from one state, the 'ON' state which permits flow of information, to the other state, the 'OFF' state which does not. The parallel connection of two gates is denoted by "x + y" (OR), and their series connection is denoted by "x • y" (AND).

A *transmission function* associated with each circuit is defined, so as to assume the value 1 when there is a path from one terminal to the other through which information flows, and the value 0 if there is no such path.[179] Transmission functions, expressed in the form of logic functions, are said to represent the circuit(s), and circuits are said to be a *realization* of functions.

Combinational logic circuits are circuits whose outputs are only functions of the present circuit inputs. Generally, they consist of combinations of basic logic function building blocks. Most digital systems, however, use circuits capable of storing information and performing logical or mathematical operations upon the stored data. The outputs of these circuits at any given time are functions of the external inputs, as well as of the stored data at that time. Such circuits are called *sequential* circuits, and are said to be a realization of *sequential machines* which, in turn, are abstract models representing sequential circuits with a finite number of input and output terminals and a finite number of internal states.[180] Likewise, a *finite state-machine,* an abstract model representing synchronous sequential machines, is described as a sequence of events that occur at discrete instances (triggered by clock pulses, for instance, or by other triggering events), where past machine state histories determine the next machine state.[181]

Logic functions design is an integral part of most if not all designs of electronic circuits used for digital operations. Logic functions are often referred to as circuit *transfer functions* because they describe the path input variables take to reach the output, much like a single gate transfer function. Accordingly, logic functions design is not independent from the circuit design since both share similar design specifications or "ideas." Frequently, however, logic operations can be implemented in more than one way, each using a unique logic function. Logic functions, in turn, can be "expressed" by taking the form of words or symbolic description of variables' input-to-output relationships, Truth Tables, Karnaugh Maps, logic equations, schematic representations, state-machines, computer design entries, or wave-form graphic representations.

In many cases logic functions do not stand alone. Rather, they are

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179. *Id.* at 59.

180. *Id.* at 241.

181. *Id.*

elements dictated by efficiency considerations. That is, their definition and expression is constrained and dictated by other circuit components. Additionally, logic function may be solely comprised of 'stock', standard or widely known and commonly used elements.

In summary, logic functions can be reproduced on many types of material objects[182] having different internal structures, and their expressions will assume forms that vary with the type of device in which such functions are embodied.[183] Their principal behavior, however, will not change. Hence, a logic expression representing a logic function which is embodied in a discrete logic circuit may not necessarily be similar to an expression of the same function implemented in a memory device, nor will it be similar to one implemented in a user-configurable device. This point is important because it is relevant to the meaning of the term computer program and the scope of literary works under the Copyright Act,[184] and in turn, it bears upon the copyrightability of logic functions.

C. Logic Functions Embodied in Microprocessors

Microprocessors, devices that by their nature provide solutions to processing problems, came to be known as central processing units (CPUs) and the so-called brains of computers, instruments, industrial equipment, appliances, games, and other electronic products. General purpose microprocessors satisfy most computer-based data processing applications and a host of other design applications from high end instruments to low end products. The task of putting general purpose microprocessors to work to solve specific problems fostered a host of peripheral devices. Some are designed to increase (arithmetic) processing power, others are designed to unburden the microprocessor from peripheral interface chores. These peripheral devices have helped spawn the development of function-specific or dedicated microprocessors, better known as microcontrollers. Generally, microcontrollers consist of a microprocessor, a memory, and other function-specific devices on a single chip, thus, forming a single-chip computer that adds low-cost minimum-hardware intelligence to consumer and industrial products.

Microprocessors[185] are offered in different architectures and ranges of processing power and sophistication. Therefore, they do not conform to any

182. 17 U.S.C. § 101 (1976). "'Copies' are material objects . . . in which a work is fixed by any method." *Id.*

183. Read Only Memory (ROM) and Random Access Memory (RAM) devices, microcontrollers, microprocessors (CPU), Reduced Instruction Set computer devices (RISC), discrete logic devices, user-configurable programmable logic devices (PLA, GLA, FPLA, CPLD) etc., have different structures which determine their logic density (logic integration capacity), the form which logic functions expressions will take, their operating speed, etc.

184. A computer program is defined as a set of statements or instructions "to be used directly or indirectly in a computer." 17 U.S.C. § 101 (1976).

185. Microprocessors, microcontrollers, and RISC devices (application specific Reduced Instruction Set Controllers) will be collectively referred to as microprocessors.

single model which can faithfully represent all their functional elements. However, some of their common characteristics stand out and can be described using a single model. All microprocessors execute a set of arithmetic or logic instructions selected from a distinctive fixed repertoire or vocabulary, known as the *microcode, op-code* or *micro-instructions set.*[186] Op-code stands for operation-code, which is a binary code.[187] Each op-code receives a unique interpretation and is designated a specific instruction *mnemonic.*[188] The CPU interface unit is configured to fetch these instructions, one instruction at a time, from an external or on-chip main memory (usually read-only memory (ROM)). Instructions execution, on the other hand, is the responsibility of the instruction control unit which, in general, consists of a microcode storage ROM, an instruction pointer or program counter, a microcode sequence controller, an instruction queue storage, an instruction decoder, an arithmetic logic unit (ALU), a memory address generator, and general and temporary registers for operations' status flags, and data storage and manipulation.

When a microprocessor executes an instruction it does not perform it directly. Rather, the instruction decoder interprets the op-code it extracted from the instruction queue, and translates it into a corresponding address of a *specific microroutine* entry point. Each microroutine corresponds to a specific microcode and consists of a unique set of logic and arithmetic operations which are implemented in a digital circuit. Such circuits embody one or more basic logic function blocks or the more complex combinational logic blocks or sequential machines. Alternatively, the logic operations can be implemented in ROM or in programmable logic array (PLA). Microprocessors often use a programmable logic array (PLA) to store the entry points for microroutines. "Typically, the microprocessor's instruction-decoder PLA contains the entry point addresses for the [microcode storage], enabling the microcode engine to begin operation at the appropriate point to execute instructions just decoded."[189]

The ALU performs arithmetic and logical operations and provides for data movement among the registers, memory, and other peripheral devices also known as input/output (I/O) devices. Finally, instructions execution sequence can be interrupted and resumed under the control of the interrupt

186. For a detailed explanation of how microcode functions, see Mislow, *supra* note 79, at 744.

187. A binary code can consist of a nibble, a byte, etc. (*See supra* notes 163 and 164).

188. For example: "ADD" (add byte or word), "AND" (logical AND), "CMP" (compare), "EOR" (Exclusive OR), "MOV" (move byte or word), "IN" (input byte or word), "LEA" (load effective address), "NEG" (negate or logical NOT), "BSR" (branch to subroutine), etc. Each of these op-codes corresponds to a specific bit pattern. *See* Intel Corporation, *80C186EB/80C188EB, User's Manual* § 2.1 (May 1990); and Motorola Inc., *MC68000 16-/32-BIT Microprocessor*, at 1-4 (Oct. 1985).

189. Slater & Belgard, *supra* note 80, at 4.

logic circuit that responds to triggering events.[190]

From a copyright law prospective, a brief overview of a microprocessor design process indicates a number of design phases: (1) the "idea" phase—design concepts and design considerations; (2) the "expression" phase—design entry and expression of the op-code set, then the micro-routines, and lastly the logic functions expressions; (3) the "design verification" phase—comparing design objectives with the resulting expressions which are either embodied in a prototype or used for logic simulation; (4) the (optional) "system integration" phase—combining the CPU with peripheral devices to form a verifiable functional unit; and, (5) the "production" phase.

D. Logic Functions Embodied in Programmable Logic Devices

One of the fastest-growing segments of the semiconductor industry is the design, manufacture and marketing of digital user-configurable integrated circuits (ICs) used to implement custom logic functions. They are collectively known as *Programmable Logic Devices* (PLDs).[191]

PLDs range in density from hundreds to tens of thousands of useable gates and can easily integrate a large assortment of logic functions into one device. Unlike PLDs, off-the-shelf discrete logic ICs provide specific logic functions and cannot be modified to meet individual circuit design requirements. The hallmark of PLDs is design flexibility, design simplicity and speed, and above all, cost-effectiveness and diversity of logic functions. PLDs can implement any Boolean (logic) expression, state machine, waveform generator, or timer, using their built-in array of logic structures—*logic cells*, or *macrocells*. Most PLDs are function specific, that is, embody specific types of logic function blocks, be it basic, combinational, or state machine blocks.

PLDs are offered in different architectures and cell-to-cell interconnect schemes as well as in a variety of memory technologies for configuring the

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190. *See* Intel Corporation, *80C186EB/80C188EB, User's Manual*, § 9.1 (May 1990); NEC Electronics Inc., *Microcomputer Products Short Form Catalogue*, at 2-2 (1989); Motorola Inc., *Microprocessor, Microcontroller and Peripheral Data, Volume II*, at 3-1562 (1988); and Texas Instruments Inc., *Master Selection Guide, Catalogue of Semiconductor Products*, at 4-9 (1986).

191. This section provides an overview of the programmable logic devices family which includes: simple and high capacity PLDs, CPLDs (Complex PLDs), EPLDs (Erasable PLDs), FPLDs (Field PLDs), PLAs, GLAs (Gate Logic Array), GALs (Gate Array Logic), etc. No specific mention, however, other than a general technology description, will be made of any specific devices. The following sources were used as a reference: Lattice Semiconductor Corporation, *Lattice Handbook*, §§ 2-5 (1994); QuickLogic Corporation, *QuickLogic; Very High Speed FPGAs*, § 1 (1994); Altera Corporation, *Data Book*, §§ 1, 2, 7 & 9 (1993); Xilinx, Inc., *The Programmable Logic Data Book*, §§ 1-3 (1994); Cypress Semiconductor Corporation, *CMOS Data Book*, §§ 4 & 5 (1987); Advanced Micro Devices, Inc., *PAL Device Data Book*, § 1 (1992); and Texas Instruments, Inc., *Programmable Logic, Data Book*, §§ 1 & 3 (1988).

devices. Some are pre-configured before printed circuit board insertion,[192] others are in-circuit configurable.[193] A third group to which GALs belong, are one-time configurable devices using logic functions built into custom made mask-works.[194] The modern counterpart of this group, hardwired logic cell array (LCA) devices and masked-programmable logic devices (MPLDs) are advanced mask versions[195] of the in-circuit configurable devices, usually used in high-volume applications (justifying the initial non-recurring design and pre-manufacture costs). These differences are attributed, in part, to the variations in logic capacity (number and types of macrocells), system features (internal macrocells interconnectability) and design method (mask work implementation, or software configuration).

Because of the PLDs' extreme diversity and versatility, they do not conform to any single model which can faithfully represent all their functional elements,[196] much like the microprocessors above. Attempting to describe any specific device would do injustice to the others. However, some of the programmable devices'[197] basic structure attributes are common, at least conceptually.

Accordingly, PLDs can be described as function specific "black boxes" with a certain number of terminals. The terminals provide a means of connecting the inner-circuitry with other external devices. Typically, apart from power-input and ground terminals, all terminals are user-configurable and can be defined as input, output, or bidirectional terminals. Internally, the structure is far more complex. The best way to describe the internal topology of such devices is to draw an imaginary grid of horizontal and vertical conductor leads that run in between a set of logic function-blocks (cells), each of which is either a standard basic block, a combinational logic block or a

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192. For example, EPLDs and PALs whose configurations are analogous to "burning" PROMs (programmable ROMs). Burning means using electrical impulses to imprint each byte of information in a designated address. In so doing, each impulse sets a switching circuit (ROM cell) to "ON" or "OFF" state which represents the corresponding bit value, 1 or 0. As mentioned before, bytes can represent program code (op-code) and data. Similarly, impulses fed to PLDs join logic cells by setting to "ON" interconnection paths. *See generally supra* note 180.

193. For example, FPLDs and CPLDs whose configuration is analogous to using impulses to "write" data to RAM, but, unlike ROMs which retain the data, the data disappears (and so does the FPLA, or CPLD configuration) when the power is turned off. In a Programmable FPLA device, the logic functions, the placement of combinational logic blocks, and the interconnections are determined by the configuration program data, loaded and stored in internal static-memory cells. The program data is, in turn, used to reconfigure the FPLA each time the power is turned on. Hence, the term in-circuit configurable. *See generally supra* note 182.

194. For a definition of mask work, see *supra* note 82.

195. These versions use the information from the programmed FPGA design files. Xilinx, Inc., *Hardwire Data Book*, § 2 (1994).

196. Notice that each group within this family of devices is uniquely labeled (e.g. PAL, PLA, FPLA, GAL . . .). Most labels are used industry-wide, and they typically represent the unique character which defines each device. Others are designated by the manufacturers and are associated with a trademark. This article is using the term PLDs as a generic label encompassing the entire family.

197. Distinguished from devices whose logic functions are one-time configurable in mask work.

sequential machine, some are universal, others are unique. A device may consist of a fixed set of identical cells or diverse cells, arranged in a single array form or a matrix form.[198] The cells are interconnected using a user-defined interconnection scheme by which either permanent or temporary fusing of selected grid lines intersections occurs thereby providing electrical contacts between them. Hence, the term user-configurable. The user-defined interconnections provide routing paths to connect selected inputs, outputs, and logic blocks, thereby creating custom integrated circuits.[199] Additionally, an interconnection scheme can be configured to create logic functions, or combinations thereof, which consist of a sum-of-product-terms or a product-of-sum-terms.[200]

PLD designers use common design entry tools, such as schematic capture or high-level behavioral language, to translate their digital circuit design (or logic function design) into a target architecture format. Design entries can be any one of the following: graphic design entry depicting schematic diagrams, text design entry using a hardware-description language,[201] waveform design entry describing output-input signals relationship, or design libraries.

Consider, for example, behavioral design. Behavioral design defines the functionality of a logic circuit by using a text-based language as design entry rather than a schematic. The text describes the circuit data and, in effect, the circuit topography along the paths which each of the input signals will take to reach the output, or an intermediate destiny. A behavioral design can be created as a single top-level computer file which contains all design control information and behavioral equations, or in a hierarchical format which contains equations in one or more include files linked through a top-level file.

198. FPLAs, for example, are a collection of universal logic elements in an interconnection framework that often resembles a grid. They typically have short programmable, routable interconnection lines that join logic elements having granularities from simple gates to large macrocells. CPLDs on the other hand, have structures of multiple PALs interconnected by long, fixed, on-chip routing resources that usually interconnect via a programmable interconnect switching matrix, or a look-up table. John Gallant, *High Density PLDs*, ELECTRONIC DESIGN NEWS (EDN), Mar. 16, 1995, at 31-32.

199. Additionally, a new family of erasable CPLDs that features static RAM (SRAM) based, programmable, logic-array blocks which appear as a sea of programmable bits that can be configured to create "megafunctions," such as CPU cores, will debut in July, 1995. *See id.* at 33.

200. These are elements of a logic function as described above in the introduction section. e.g.:

$$f(a,b,c) = a'b'c' + abc + abc'; \text{ or, } f(a,b,c) = (a+b+c)(a'+b+c')$$

201. Design tools for FPLDS, for example, enter circuit data via hardware-description language (VHDL) or Verilog, which handles the complex schematic entry that high-density circuits require. *See* Gallant, *supra* note 195, at 31-32.

The following two file excerpts are presented as an illustration:[202]

Example File 1:	Example File 2:
TITLE COUNTER EXAMPLE FILE CHIP COUNTER #XXXX; ;Pins (not in pin # order) CLK REGWR SELECT COUNT_ENB DD0 DD1 DD2 DD3 OUT_ENB COL0 COL1 COL2 COL3 CARRY GND ;Nodes LOAD HOLD COUNT ;COUNTER EQUATIONS LOAD = (REGWR * /COUNT_ENB); HOLD = (REGWR * COUNT_ENB + /REGWR * /COUNT_ENB); . . . CARRY := (DD3 * DD2 * DD1 * DD0 * LOAD + /LOAD * COL3 * COL2 * COL1 * COL0); . . .	INPUTPIN a b c d e f g OUTPIN (FOE =out_trst) out FASTCLOCK out_clk; . . . PARTITION FEB out; place this function into Fast Function Block EQUATIONS out := a * B* C * d * e out.clkf = f * g; use global FastCLK out.trst = /h; . . .

202. Xilinx, Inc., *XACT, XEPLD Design Guide*, at 1-5, 5-27 (1994).

A compiler interprets the files and produces translations in the form of include files or files ready to be loaded onto the device being configured.[203] It is important to note that, frequently, dissimilar device configurations can produce similar device functions (behavior), which means that cell interconnections are different but the end result is functionally the same.[204] The variations are usually attributed to variations in design entries' expressions.

A typical PLD design and development process requires great skill, and a substantial investment of resources, including development systems which convert design entries into PLD fuse maps or any other PLD configuration formats such as switch matrix programming format. Furthermore, a PLD designer may go through several iterations of many design steps in order to reach the design target.

An examination of a PLD design process from a copyright law practitioner's perspective, reveals several design phases: (1) the "idea" phase—design concept, design considerations, and device selection; (2) the "expression" phase—design entry and expression; (3) the "design verification" phase—comparing design objectives with the resulting expression which is either embodied in a prototype or used for logic simulation; (4) the (optional) "system integration" phase—combining the PLD with other devices to form a verifiable functional unit; and, (5) the "production" phase.

E. Logic Functions Embodied in Memory Devices

Last but not least, memory devices can embody expressions of logic functions. Unlike PLDs and CPUs, memory devices are not as versatile, but for some logic functions applications they are very useful. Typically, such applications will involve a series of relationships between a set of variables (say, 4 input bits) and a set of results (say, 8 output bits). These relationships can be expressed in the form of logic equations, or a Truth Table, where every 1 and 0 combination at the input produces a resulting 1 and 0 combination at the output.

When implemented in ROM, each combination of input variables constitutes a ROM address, the contents of which constitutes a corresponding result. Accordingly, the relationships can be translated into a single column table where each table entry is 4, 8, or 16 bits wide and is separately addressed starting at 00...0 and ending at 11...1, or some lower number. Any table entry address for which an input variable combination exists receives a value equal to the desired result, the others are *"don't care"* entries.

Once again, a design process using ROMs involves several steps which, from a copyright law practitioner's perspective, can be divided into: (1) the "first idea" phase-design concept, design considerations, and device type

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203. *Id.* § 1.

204. Analogous to a maze that can be traversed from beginning to end in various ways.

selection;[205] (2) the "expression" phase—design entry and idea expression—function table creation; (3) the "second idea" phase—specific ROM selection (4) "design verification" phase—comparing design objectives with the resulting expression which is either embodied in a prototype or used for logic simulation; (5) the (optional) "system integration" phase—combining the ROM with other devices to form a verifiable functional unit; and, (6) the "production" phase.

205. ROM devices have fixed structures. Their content, however, can be modified. ROMs can be viewed as a two dimensional array of cells. For example, an array of 128 x 8 means 128 rows and 8 columns. This correlates to a ROM with 128 addresses each containing 8 bits, one bit per cell. Accordingly, the process of selecting a suitable ROM involves matching the ROM's width and number of addresses to the width and length of the table which is to be embodied ("fixed") in it.