Essential Issues for IP Reuse

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Abstract

With widespread recent emphasis on System-On-a-Chip (SOC), IP reuse has emerged as a vital and growing business in semiconductor industry. In this paper, we will address essential issues for IP reuse by discussing current challenges to the success of IP businesses and identifying the obstacles that need to be overcome.

1. Introduction

Due to the rapid advance of fabrication technologies, silicon capacity is doubling every 18 months. This allows companies to build more complex systems on a single chip of silicon (System-On-a-Chip, SOC). However, their ability to develop such complex systems in a reasonable amount of time is diminishing with that increase in complexity. The gap between silicon capacity and design productivity seems to be widening at an ever greater pace, slowing the growth of the semiconductor industry.

In order to solve the productivity gap problem, three approaches have been proposed: (1) platforms, (2) reuse and (3) synthesis. In the platform approach, semiconductor vendors provide a universal SOC platform consisting of one or more core processors and many smaller peripheral processors for handling different I/O protocols and encoding/decoding functions. In the reuse approach, it is assumed that SOC designs will be assembled from many different blocks of IP provided by a variety of sources. In the synthesis approach, the SOC chip will be synthesized from a high-level functional description using a common language such as C, and tuned for particular applications and fabrication technology.

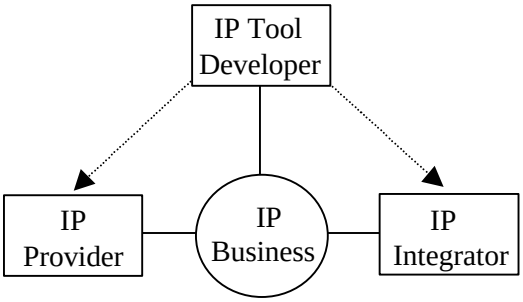

Figure 1: IP business model.

In this paper, we will discuss the reuse approach. Reuse, as a solution to the productivity gap, has created a whole new branch of semiconductor industry, called IP (Intellectual Property) business, as shown in Figure 1. There are three major players: (1) IP providers, (2) IP integrators and (3) IP tool developers. IP providers supply IP components, including hard cores, soft cores and software components. IP integrators are typically designers in system houses. IP-tool developers provide IP providers and integrators with design methodologies and tools to support IP development and system integration. Another important element in IP business is the business models for IP distribution, service, and trade.

In the past few years, the SOC design and IP reuse trend has driven most semiconductor companies onto the IP-business bandwagon. Organizations such as VSIA (Virtual Socket Interface Alliance) and VCX (Virtual Component Exchange) have attracted large numbers of companies in order to define the rules for IP reuse and trading. Major electronic corporations have launched projects to develop IP databases, reuse methodologies, and build up SOC design infrastructures. Many small companies with one or more pieces of IP have started to offer their IP to the public via Internet. Independent design

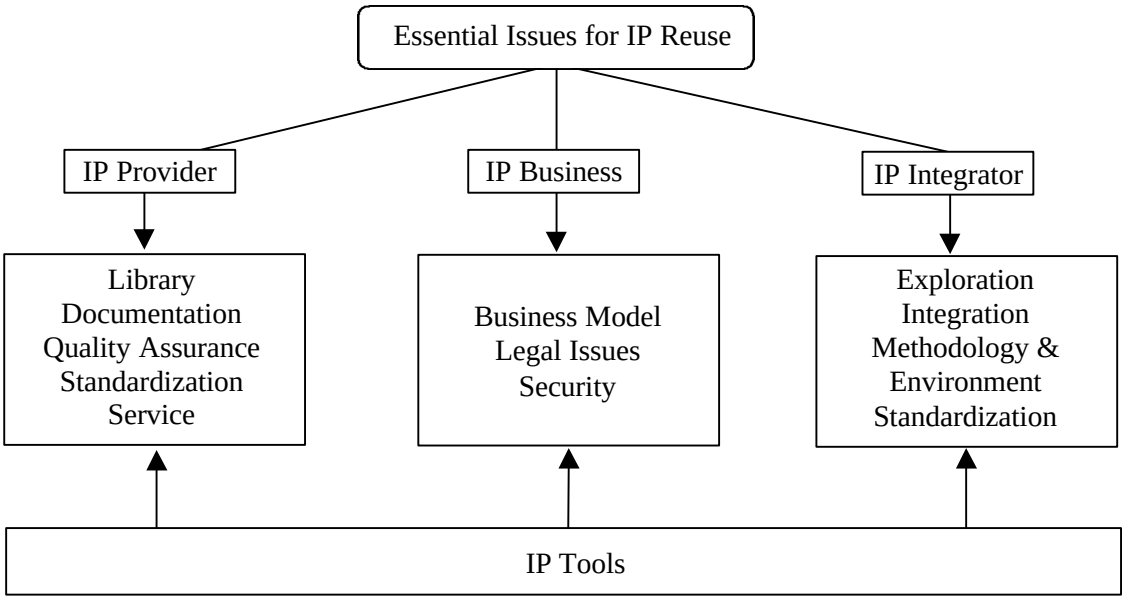

Figure 2: Essential issues for IP reuse.

houses as well as design divisions in large corporation are also trying to package their existing cores and sell them as IP. System design houses have started to evaluate IP for reusability and ease of integration. In the EDA industry, the majority of recently announced tools are now labeled for IP and SOC use.

Despite all this efforts and support from the semiconductor industry, there are still many challenges to successful IP business. In this paper, we will address the essential issues for IP reuse, as summarized in Figure 2.

2. Essential Issues

2.1 IP Provider

In a broad sense, IP means Intellectual Property that can be bought and reused. It is basically a know-how technique that can be in the form of algorithms, software, designs, models, test benches, or methodologies. This know-how can be modified and tuned to a particular application. Every designer in every company uses old know-how in their new designs and products. Capturing this information, distributing and reusing it represents the core of IP business.

In a narrow sense, IP means a virtual component (VC) with well-defined functions, usage method, and tools to support its usage. In other words, a VC is a ready-to-use product. In this paper, we look at IP industry in a broader sense, although it's ultimate goal is to become a VC industry after the standards for IP definition, trade and reuse are accepted.

In the IP-provider arena, the essential issues include:

- **IP Library**

The first problem facing IP provider is IP definition in terms of functionality, style and type. An IP can be a single-instance commodity-style IP or a parameterizable-style IP. As shown in Figure 3, the increasing generality of an IP done to increase the value/market of the IP will also make it more difficult to optimize, verify and test the IP.

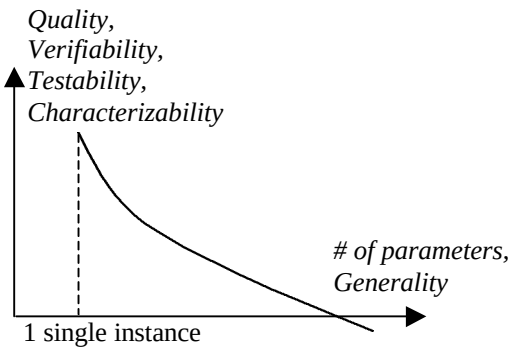

Figure 3: IP definition.

The second problem facing IP providers is how to convert a legacy code or design into a reusable IP. Any solutions must take into account all design aspects from IP integrators, such as expandability (e.g., many designers like to add new features to the IP), testability and technology migration.

The third problem is whether to offer IP as hard or soft IP. Hard IP is predictable but not portable. In other words, they can be easily characterized and used but they can not be modified and easily migrated from one technology to the other. On the other hand, soft IP is portable but not predictable since they must be synthesized and verified before use. The main challenge is to develop IP that is both predictable and portable; e.g. *firm* IP.

- **Documentation**

Developing reusable IP is usually a time-consuming task in which a large portion of time is devoted to preparing volumes of documents, including data sheet, user manuals, simulation and reuse models, test benches and technology migration guidelines. From the users' point of view, good documentation should be concise, comprehensive and complete.

Organization of catalogs or databases for IP, and the format and content of IP information for query search and evaluation, is another issue for IP providers. Although much work has been done in this area, information for automated or semi-automated reuse, and for migration and parameterized quality assessment is still missing.

Another problem concerns standardization of database queries for IP search so that the same query language can be used over multiple databases. Solving this problem is critical to ease of selection of IP for subsequent use.

- **Quality Assurance**

Today, many system companies are still reluctant to adopt IP from third-party vendors because of quality assurance issues. The first problem is that most soft IP from third-party vendors has not been verified in silicon. Hence, reliability and performance are not well known.

The second problem is that it is difficult to verify that the given IP is functionally correct and delivers what it promises in the specification for all values of all parameters.

A final problem is that it is difficult to demonstrate that the verification methods and test benches provided by the IP vendor are sufficient to test the IP alone and also when integrated into an SOC.

- **Standardization**

The main purpose of standardization is to facilitate the IP integrator's reuse process. Today, an IP integrator often needs several months to evaluate IP. When he/she is involved in a multi-vendor evaluation, the situation becomes even more complex. Each IP vendor may have its own specification and documentation style. In order to perform "orange-to-orange" comparisons between IP from different vendors, the user may have to perform a series of conversion procedures. This is both tedious and time-consuming.

- **Service**

The final and possibly most important issue is service. Unless IP vendors can guarantee complete documentation, full quality assurance, and a single, easy reuse methodology, they have to provide full services to IP integrators so that the latter can successfully incorporate their IP into systems.

2.2 IP Integrator

In the IP integrator arena, the essential issues include:

- **Exploration**

With IP swamping the market, SOC integrators need a mechanism for design exploration. First, designers need to know what design alternatives exist and which IP/cores fit those alternatives. Second, designers need to explore IP provided by different vendors but having similar functionality in order to select the most suitable one for their design. Hence, an easy-to-use design exploration technology is required to facilitate the IP selection process for system integrators.

- **Integration**

System integration by reusing existing IPs/cores is not a trivial task. In order to successfully reuse existing IP/cores, designers not only need to fully understand IP specifications but also need to rely on support provided by IP vendors. In addition, designers also need to consider interface design and testing, which may increase design overhead considerably. Furthermore, design testing and verification issues may complicate the integration process.

- **Methodology and Environment**

One of the key factors for system companies to adopt IP/core reuse is to create a design-for-reuse culture in the company. Most todays' system companies have not yet supported a company-wide design-for-reuse strategy. Hence, the design-for-reuse methodology and environment have not been introduced into their infrastructure. Establishing the infrastructure for design-for-reuse is the most important first step for embracing the design-for-reuse culture. Without an infrastructure, imposing such a culture by itself may not be a good strategy.

Furthermore, in today's design practice, most system companies are using an RTL-based design environment. This method is not sufficient to support IP reuse. In order to adopt IP-reuse strategies, integrators will have to move design entry to higher levels of abstraction. To accomplish this, SOC modeling for IP reuse and IP-centric methodologies are needed.

- **Standardization**

From the standpoint of system companies, acquiring IP from third-party vendors is done through a lengthy and expensive bilateral negotiation with the vendor whereby pricing, service, and many other issues are worked out. If multiple third-party vendors are to be considered, the negotiation process must take place for each vendor. A standard for the IP acquisition process is needed.

IP specification standards are needed so that system companies can use simple plug-and-play strategies to evaluate new IP.

Reuse of IP/cores raises many new design issues in testing and verification which will also require standardization to make efficient IP-reuse environments possible.

2.3 IP Business

- **Business Model**

Currently there is no clearly defined business model for IP that encompasses pricing, service, legal issues and security. IP trading is typically conducted with private negotiations between IP provider and IP user, often taking several months or more to complete.

IP business involves not only bilateral contract negotiation but frequently multiple-party negotiation. For example, a system company licenses an IP from an IP provider. In the mean time, the system company also subcontracts a third-party vendor to perform the design verification procedure. Hence, the third-party vendor also needs to acquire the IP in order to perform the verification procedure. This will further complicate the contract negotiation process. Hence, different IP business models are needed to solve different IP trading scenarios.

- **Legal**

Legal issues are still very much a gray area in IP business. Some legal issues can be secured using contracts. Copyrights and patents can be implemented to protect intellectual property. However, unless IP providers can completely define the legal responsibilities of IP users, the latter must always be under the threat of legal action for infringing intellectual-property rights. A total legal solution is necessary for the success of IP business.

- **Security**

IP business is built on the foundation of intellectual property. Naturally, security is one of the main concerns in the IP business. One way to secure intellectual property is by using legal procedures, as previously mentioned. However, such methods are not iron-clad. As IP trading moves onto the Internet, better security methods are needed.

2.4 IP Tool Developer

The EDA industry should play a pivotal role in the success of IP reuse. While IP vendors are proliferating and system companies are eager to jump onto the IP-reuse bandwagon, the EDA industry has lagged behind. Even though most new EDA tools are labeled for IP-reuse and SOC design, they lack a systematic design methodology to support IP reuse. In the IP tool arena, we can divide the essential issues into following three categories.

- **Support for IP Provider**

From the IP providers' perspectives, there is a need for new tools and methodologies to facilitate IP development and sales. First, tools for easy technology migration of IPs are needed to keep up with the fast pace of technology advances. In addition, a standard verification and testing methodology is required to improve the quality assurance of IPs.

Second, tools for supporting documentation preparation and searching are very important to both IP providers and users. Using such tools, IP users can easily understand the IP and learn the IP-reuse procedure without searching through hundreds pages of documentation.

Third, an easy-to-use and comprehensive IP search method is needed to facilitate IP selection and evaluation for the IP integrator. This tool should provide the IP user with not only a list of usable IPs but also an IP analysis mechanism. Using such a tool, the IP user should be able to analyze IP's tradeoffs, and perform comparisons between IPs provided from multiple vendors.

- **Supporting IP Integrator**

From the perspective of system companies, the most urgent issue is to develop an IP-centric design methodology and an environment to support such a methodology. To accomplish this goal, we have to develop techniques to solve IP-centric exploration, synthesis, verification and testing problems.

First, tools and methodologies supporting high-level design abstraction beyond the RT level are needed to support IP reuse. The problems, such as specification styles, languages and design models, need to be solved. Second, a design exploration and IP evaluation methodology and its supporting tools are needed to facilitate the IP-centric design process. Third, a reuse-automation design methodology is needed to alleviate the tedious system integration process. Using a reuse-automation tool, the designer can generate the final design by automatically integrating IPs without suffering through a time-consuming and error-prone manual design process. Fourth, a verification and testing methodology and its supporting tools are needed to support IP-level as well as system-level design verification and testing. Finally, we need to integrate all the above methodologies and tools to form an IP-centric design environment.

- **Supporting IP Business**

For IP business, tools and methodologies are needed to solve IP security problem and support IP distribution. The security problem is the most sensitive issue in the IP business. We need to develop protection-and-detection techniques and supporting tools to protect and secure the

intellectual property right. In addition, most today's IP trading and transactions are conducted via Internet. Hence, we need to develop internet security techniques and it's supporting tools.

3. Current Status and Future Trend

After a three-year effort from all parties in the semiconductor industry, we have achieved tremendous progress in many areas. VSIA and VCX are the two main forces in setting the definition of variety of standard procedures for IP business. VSIA has launched a variety of development working groups (DWGs) to define technical standards. Many of them are rolling out this year. VCX has also launched a number of DWGs to define IP trading standards for IP exchange. A pilot run of commercial transactions is scheduled in the second half of 1999. Despite the great efforts by the VSIA and VCX, there are still many obstacles that must be overcome in the forthcoming years.

In the past few years, we have seen a proliferation of IP providers. However, very few IP providers have become successful IP suppliers. The business model is still unclear.

Many system companies have investigated and attempted different design reuse strategies. Although some progress has been reported in the past few years, many technical issues, such as IP-centric design methodologies and environments, and business models remain open problems.

On the EDA side, despite many recently announced new tools labeled for IP reuse, a clear IP-centric design methodology does not exist. Nevertheless, some progress has been achieved by the EDA industry. For instance, the Reuse Methodology Manual (RMM) provides the users with a guideline for design-for-reuse. In addition, Mentor Graphics Corp. and Toshiba have recently demonstrated the viability of a methodology for core-based design.

Even through there are still many obstacles needed to be solved, the IP business is a tremendous opportunity and a challenge. It will require time and a team effort from the semiconductor industry to make it happen.

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