

Open-Source VLSI CAD Tools: A Comparative Study

L. Jin, C. Liu and M. Anan

Dept. of Electrical and Computer Engineering

Purdue University Calumet, Hammond USA

Email: muhammad.anan@calumet.purdue.edu, Phone: 219-989-2483

Abstract

The design of electronic circuits can be achieved at many different refinement levels from the most detailed layout to the most abstract architectures. Given the complexity of Very Large Scaled Integrated Circuits (VLSI) which is far beyond human ability, computers are increasingly used to aid in the design and optimization processes. It is no longer efficient to use manual design techniques, in which each layer is hand etched or composed by laying tape on film due to the time consuming process and lack of accuracy. Therefore, Computer Aided Design (CAD) tools are heavily involved in the design process. In today's market, there are plenty of VLSI CAD tools; however, most of them are expensive and require high performance platforms. Selecting an appropriate CAD tool for academic use is considered as one of the key challenges in teaching VLSI design courses. In this paper, number of open-source and freeware CAD tools are presented and evaluated. Based on the objectives of the user, this paper furnishes guidelines that help in selecting the most appropriate open-source and freeware VLSI CAD tool for teaching a VLSI design course.

Keywords: VLSI, CAD Tools, Electric, Magic, Alliance, Comparative Study

I. INTRODUCTION

More than 50 years after the first integrated circuit (IC) was invented, the number of transistors integrated on a single chip has grown to a dramatically high value, which is about two billion transistors on a quad-core Itanium designed by Intel in 2009 [1]. Also the number is still significantly increasing in order to make the devices smaller, more powerful and less power consuming. However, along with the increasing number of the transistors on a single chip, the non-ideal phenomena will become much more serious in runtime, such as more significant leakage, higher adjacent capacitance, etc. Such phenomena will potentially affect the functionality of the chip. Therefore, the phenomena must be taken into account throughout the whole design work flow. Based on this consideration, the chip design became increasingly complex. The complexity of the Very Large Scaled IC (VLSI) is far away beyond the human ability, hence the Computer Aided Design (CAD) tools are involved in the design.

For the smaller scaled ICs, highly customized ICs, and some specially required ICs, the bottom-up method is usually acceptable to use [2]. The bottom-up method means design a chip from every single transistor, wire and conjunction. The bottom-up method leaves most of the options and parameters to the designers to optimize. In particular for the specially required ICs, it is almost the only way to design. But the most serious disadvantage of this method is the efficiency and flexibility is very poor. Therefore, this method is not suitable for the VLSI design.

Based on the complexity of arranging large amount of the transistors in a relatively small space, the VLSI design is commonly based on the top-down method [2]. This method, in contrast with the bottom-up method, mainly designs circuits by splitting a function into modules, implementing modules separately and then connecting each of the modules together. This method can be highly automated nowadays along with the development of the computer technologies. Many functions such as inverter, NAND gate, etc., are ready-for-use components in CAD software. The design of VLSI has been simplified to combine blocks together, check the layout then optimize manually or based on automatic optimization techniques. Also, some software packages have the ability to check the logic, schematics and layout, and find potential problems in the design.

In today's market, there are lots of VLSI CAD tools available for use. Some of them are free while the others are not. A proper tool that is suitable to the specific design task can lead to high efficiency and less cost. The choice of the CAD tools is very critical and concerns the users more and more. Also for educational purposes, an intensive CAD tool is fairly useful for the students to understand the design and concepts of VLSI. In this paper, some open-source VLSI CAD tools such as Electric, Magic and Alliance have been selected for comparison purposes.

II. VLSI CAD TOOLS

Based on the typical VLSI design work flow, a good VLSI CAD tool must support the following basic features: logical design, circuit schematic design, layout generation, and design check. In today's market, most VLSI CAD tools are based on Unix or Linux platforms. Only few of them have the ability to run in Windows or run independently of certain emulation/simulation software.

Considering the popularity of the VLSI CAD tools, three kinds of commonly used and freely available tools were selected for comparison in this paper. They are, as mentioned earlier, Electric, Magic, and Alliance. Both of Electric and Alliance are available under the GNU General Public License (GPL) [3, 4]. Magic, which was developed back in 1980's, is available under Berkeley Open-Source License [5]. For the commercial software side, another popular tool used at the academic institutes is OrCAD PSpice [6]. This tool is a variance of the SPICE tool family. It offers student demo version with full function but limited capacity. It is now a product of the Cadence Design Systems, Inc. Another tool from this company, Cadence Custom IC Design, is also very popular software in VLSI design [7]. It is capable to design, analyze and help to optimize an analog, radio frequency, or mixed-signal ICs. A basic copy of the Cadence Custom IC Design is sold for several hundred dollars. This paper mainly focuses on the comparison of open-source VLSI CAD tools for academic and educational use. Therefore, commercial software is not included in the comparison.

A. Electric

Electric is an open-source Electronic Design Automation system that was developed by Steven M. Rubin in the early 1980s [3]. The newest version is 8.09. The electric development is supported by Sun Microsystems Laboratories. The early version of Electric is written in C language, and now it is written in Java, which provides more stability and platform independence.

The major difference between Electric and other two discussed CAD tools is that Electric only uses connectivity for circuit designs while Magic and Alliance use connectivity and geometry. The system considers that nodes and arcs compose the whole circuit. Nodes are the electric elements and arcs are used to connect nodes. This can provide the following advantages. First, there will not be any node extraction, and therefore it will speed up the network-oriented operations. Second, since geometry method is not used, there are no geometry errors. Third, the entire network can be shown whenever part of it is selected, and the design can be kept well-connected.

Forth, similar to Magic, the system knows the connectivity information. Fifth, the design process is much simpler. Due to the special design style, Electric allows the user to run Layout Versus Schematic (LVS) on layouts and then clean up the design rules without worrying about losing LVS match. Sixth, IC schematics and layout can be done in one interface. However, Electric has some problem, like the user need to be good at connectivity, and when designing, the circuit may be misconnected but not easy to be found on the screen.

Unlike other CAD tools, Electric can be easily installed on Microsoft Windows. However, its robustness of operation is not so good. That means if a user did an erroneous operation, the software may get no response or directly shut down.

B. Magic

Magic is a VLSI layout tool written by John Ousterhou in 1980's, and is widely known as the earliest tool used for circuit layout [5]. The most advanced feature of Magic is its liberal Berkeley open-source license. Due to this open-source license, users could write and add their codes to Magic so that they can easily implement their ideas and at the same time it makes Magic becomes advanced. The newest stable version of Magic is 7.5 and the development version is 8.0. Both are implemented by Magic development team and can be downloaded online.

A key difference between Magic and other CAD tools is that it contains a lot of rules about circuit and uses these rules to help you design the circuit [8]. Magic is not only a color painting tool for layout. It can provide additional operations including: Built-in Design-Rule-Check (DRC), Built-in Hierarchical circuit extractor and some other useful functions such as routing tools [9]. The second feature of Magic is that the design style is based on Mead-Conway "scalable CMOS" which means it uses "lambda-based" dimensions [5]. This allows Magic to generate different output files in order to implement the same design on different processes, and convert the lambda units to physical dimension at different scales. Therefore, it is easier to write technology file for different manufactures. Third, Magic provides an operation called plowing. This operation allows the user to modify the layout without changing connectivity and layout-rule correctness [10]. All of these features allow the users to design circuits easily and with great support. However, this could also make the structure of the circuit become more complex, and therefore cost more design time.

Typically, Magic runs under Linux or UNIX platforms. In order to use Magic under Microsoft Windows, it needs the Cygwin application. This makes Magic difficult to be installed and used on Windows. However, it is still widely used at academic institutes and small companies.

C. Alliance

Alliance is a free set of CAD tools that have been developed by ASIM department of LIP6 laboratory of the Pierre et. Marie Curie University (Paris VI, France), and it is mainly used for teaching VLSI design [4]. Some main features of Alliance are as follows. First, it supports the standard VLSI description formats like SPICE, EDIF, VHDL, CIF and GDS2. Also, it supports both construction tools and validation tools. Second, all of the Alliance tools are easy to use, and it is convenient to get the documents and support online. Third, the design flow of Alliance is also based on Mead-Conway model, and is divided into five parts: capture and simulation of the behavioral view, capture and validation of the structural view, physical design, verification, and coverage evaluation [11]. Besides the proposed design flow, Alliance also has a logic synthesis system which discards the second part of design flow. To support the design flow, every Alliance tool can easily interact with each other, but at the same time they can be used independently. Forth, three basic views of chip (behavioral view, structural view and physical view) can be represented.

Alliance has over 150 documented standard cells and six custom optimized generators [12], also it does not require a high performance workstation like Cadence; however, it is designed for UNIX based platform. The

project team tried to find a version for Microsoft Windows, but failed to find one.

D. Other CAD tools

Beside the CAD tools mentioned above, there are many other CAD tools that can be found, though they are not as popular as the three former ones. Some of them are still in development and cannot be used as tools for the whole work flow. These tools have their own features and some of them really worth mentioning here.

BSIM 4 is a simulation model for SPICE3f5 and SPICE3e2 [13]. It is developed by the BSIM Research Group in the Department of Electrical Engineering and Computer Sciences (EECS) at the University of California, Berkeley. BSIM 4 is used for circuit simulation and CMOS technology development, and the latest version is BSIM 4.6.5, which is released in September 2009.

IRSIM is a logic-level simulator for MOS transistor circuits [14]. Initially, IRSIM was designed to read the “.sim” file and developed with MAGIC, but later the development team added the function of scheduling commands to make it have good performance as Verilog HDL simulators. The latest version of IRSIM is version 9.7.

TOPED is a newer cross-platform IC layout editor, which is still under active development. It is also open source software and supports GDS and CIF formats [15]. This editor focuses on the speed and quality of the screen output and has the features like session recovery and customizes GUI. The latest version is version 0.9.5 released in October 2009.

III. COMPARATIVE STUDY

Based on the variety of the operation systems at different academic institutions, three commonly used and freely available tools have been covered in this comparison (see Table 1). These tools are: Electric, Magic, and Alliance. In order to compare each of the software in a clear and logical manner, the following criteria are considered in the comparison:

1. The formats that the software supports including the formats that can be directly open or imported via some plug-ins.
2. The automatic functions such as automatic layout generation, automatic wire arrangement, etc.
3. The method of the model building.
4. The ability of output analysis including the model check function, design rule check, electrical rule check, etc.
5. The Support from author or software development team such as the availability of the help files, examples and the accessibility of the website.
6. Operation difficulties.
7. Installation difficulties.
8. System Requirement.
9. License.
10. Stability.
11. Version variation and update frequency.

	Electric	Magic	Alliance
Format Supported	Uses *.elib format. Compatible with up to 17 formats including most common formats	Uses *.mag format. Compatible with CIF, Calma and IRSIM	Compatible with EDIF, VHDL, CIF, GDS2, SPICE
Automatic Functions	PLA, Cell, Pad and ROM generator, and 5 routers	Real-time design rule checking	Automatic optimization
Method of Model Building	Visualized GUI VHDL	Script Visualized GUI	Script Visualized GUI
Output Analysis	Multiple layout and schematic check functions and simulation faster than the others	Multiple layout and schematic check functions and simulation	Multiple layout and schematic check functions and simulation
Support	Acceptable availability of the documentation and help files.	Very detailed technology files, help files and other resources available on the website	Detailed documentation, help file and resources available on the website
Operation Difficulties	Easy to use	Easy to use, but need emulation to run in windows which sometimes cause problems	Easy to use
Installation Difficulties	Very easy, only one file and independent with any other files	Depend on Cygwin when using in windows, complicated installation procedure	Can only run in Unix and need to be re-compiled when using in various version of linux
System Requirement	Java based, cross platform, multiple OS supported also C++ binaries available	Linux/Unix, OS/2, DOS	Linux/Unix
License	GNU GPL	Berkeley Open-Source License	GNU GPL
Stability	Good with Java version but poor with C++ version	Not very good in non-Unix platform	Good
Version and updates	V8.09 for Java version and C++ version discontinued	Stable V7.5, development V8.0 About 6 month between updates	Version 5, about two month between updates

Table 1: A comparison of three open-source VLSI CAD tools: Electric, Magic and Alliance.

CONCLUSION

VLSI design has become an important course at most of the electrical and computer engineering programs. However, buying licenses for commercial VLSI CAD is usually costly and requires high performance workstations which many academic institutes may not be able to afford. This paper provided some insight on the most popular open-source CAD tools that can be used in the academic field.

Electric tool shows the best compatibility with different platforms, and also have plenty of design and check functions in a friendly user interface. Magic tool, which has a long history in VLSI design, has the best technical support and documentation, and it provides both stable and development versions for different use. It is very attractive to the academic institute users. Alliance tool, which can only run in Unix/Linux platforms, has the best usage stability and good balance in functions. But its popularity is limited by its strict operation system requirement. Even in Linux, it requires a re-compile with specific compiler. It also increases the complexity of the installation.

In conclusion, Electric tool is highly recommended for Windows users. Yet, in Unix/Linux systems, Electric doesn't have significant advantage as it does in Windows. Magic and Alliance are also competitive for their own features. Magic may be more suitable for education that focuses on software development and Alliance may be good for education that focuses on design skill. This comparison is hopefully useful for those who are looking for a suitable VLSI CAD tool for academic purposes.

REFERENCES

- [1] Intel Corporation, The Intel® Itanium Processor 9300 Series: A Technical Overview for IT Decision-Makers, White Paper, February. 2010.
- [2] Neil Weste and David Harris, CMOS VLSI Design, the Third Edition, Pearson Education, 2004.
- [3] *Static Free Software*. November 2009. <http://www.staticfreesoft.com>.
- [4] *Alliance*. November 2009. <http://www-asim.lip6.fr/recherche/alliance>.
- [5] *Magic VLSI Resource*. November 2009. <http://www.opencircuitdesign.com/magic>.
- [6] *Cadence OrCAD Solutions*. February 2010. <http://www.cadence.com/products/orcad>.
- [7] *Custom IC Design*, February 2010. <http://www.cadence.com/products/cic>.
- [8] Yohn K. Ousterhout, Gordon T. Hamachi, Robert N. Mayo, Walter S. Scott, and George S. Taylor, "Magic: A VLSI Layout System", Design Automation, 1984. 21st Conference on, 25-27 June 1984.
- [9] Taylor, G. S. and Ousterhout, J. K. "Magic's Incremental Design Rule Checker", Design Automation, 1984.
- [10] Scott, W. S. and Ousterhout, J. K. "Plowing: Interactive Stretching and Compaction in Magic", Design Automation, 1984.
- [11] Alain Greiner and Francois Pecheux, "ALLIANCE: A complete Set of CAD Tools for teaching VLSI Design", Technical Report: Laboratoire MASI/CAO-VLSI, Institut de Programmation, Universite Pierre et Marie, 1992.
- [12] Amara Amara, Alain Greiner, Luis Lucas, Frederic Petrot, Franck Wajsburt, Laurent Winckel, "The Portable Cell Libraries of the Freeware Alliance CAD system".
- [13] *BSIM3 – Introduction*, February 2010. <http://www-device.eecs.berkeley.edu/~bsim3>.
- [14] *IRSIM*, February 2010. <http://opencircuitdesign.com/irsim>.
- [15] *Topped – Open Source Layout Editor*, February 2010. <http://www.toped.org.uk>.