Abstract: Tremendous growth has been observed worldwide in the electronics industry during the last two decades but Caribbean countries like Trinidad and Tobago have not yet paid much attention towards building economy based on this industry. These countries can stimulate their economic growth, jobs or new opportunities and future collaborations among private industry, government and academia through suggestions proposed in the present paper. As a case study, development of sustainable infrastructure for one of the exponentially growing area of electronics industry, that is, Very Large Scale Integration (VLSI) design for the Caribbean region is discussed. Both technical and general issues related to design of the VLSI Research Unit for Caribbean are explored to tap the Consumer Electronics market, with the help of all campuses of the University of the West Indies, industry and government.

Keywords: Very Large Scale Integration, Field Programmable Gate Array, Consumer Electronics Products, Matlab, Simulink, Xilinx Foundation Series Software, Digital Signal Processing

1. Introduction

Economy of most of the Caribbean countries depends either on petro-products or tourism. Nobody can cultivate petro-products forever due to limited natural resources and tourism industry may also face downfall due to recession all over the world. It is the demand of time that these countries should look for some other alternatives for their economic sustainability. Electronics industry seems to be a good option due to its tremendous growth rate. Something has been done in the area of telecommunication by just creating basic infrastructure but this has not yet taken the form of an industry. Next alternative, that seems reliable and realizable, is the development of an industry based on VLSI design. India has done excellent work in this area (Kishore, 2007). The VLSI design based industry can tap the entire consumer electronics market, which is growing exponentially day-by-day.

Consumer electronic products include applications ranging from household devices like washing machines, VCD/DVD players, cell phones to office equipments like fax machine, printer, surveillance, automation and control devices. Signal processing techniques or algorithms are used almost in all these consumer electronics products. The most common approach to the implementation of digital signal processing (DSP) algorithms was digital signal processors, which had brought revolutions in the market in 80s. Nowadays, this approach is not the first choice of the application developer due to large development time involved in it (Parhi, 1999). People are now looking for the technology using which any application can be developed within few days. Application Specific Integrated Circuits (ASIC) technology can be the next candidate but its development cycle is also too long. Moreover development process is very costly. Clean room facility and fabrication unit of billions of dollars are required. Field Programmable Gate Array (FPGA) can be used to alleviate digital signal processing problems with the semi-custom approach. FPGAs are programmable logic devices which bear a significant resemblance to traditional custom gate arrays and may be well suited for the design of consumer electronics products using digital signal processing algorithms (Berkeley Design Technology Inc., 2007). The advantages of DSP on FPGAs are primarily related to the additional flexibility provided by FPGA’s reconfigurability. Not only can
high-performance systems be implemented relatively inexpensively, but also the design and test cycle can be completed rapidly due to the elimination of the integrated circuit fabrication delays. This new approach also allows adapting the functions to account for unforeseen requirements. Other advantages of the FPGA based consumer electronics products include higher sampling rates than that are available from traditional DSP chips, lower costs than an ASIC for moderate volume applications, and more flexibility than the alternate approaches (Baese, 2001).

2. Suitability of VLSI Infrastructure for the Caribbean

This paper proposed development of sustainable infrastructure for FPGA based VLSI design of Consumer Electronics Products within the Caribbean region. There are many reasons for choosing this infrastructural development. First of all consider the financial aspects. Infrastructural requirement for this proposal is not very costly. It just needs a small piece of land, equivalent to Physics Department of St. Augustine campus of the UWI, to establish VLSI Research Unit. As far as research equipments are concerned, we just need few personal computers, networking facilities, some high end software, hardware and basic test equipments along with the general facilities. UWI has three different campuses around the Caribbean region and any of the campus can provide these infrastructural facilities without any difficulty.

The second aspect is human resources, which can be easily managed from various UWI campuses themselves. For this pilot project, skilled faculty members and students from physics, mathematics, computer science and electrical engineering departments will be needed to carry out research and development. A research group can be made easily by gathering like-minded researchers from the UWI. Already a lot of UWI researchers are working towards VLSI, just a common platform like VLSI Research Unit is needed.

The third aspect is the utility or benefits of the proposal. Any digital application, particularly related to consumer products, can be realised on FPGAs (Cofer and Harding, 2005), and trends reveal that consumer electronics products have very big market worldwide. So lot of revenue can be generated through the production of these products and consultancy in this area.

The fourth aspect is sustainability of proposed development. Any industry can sustain itself for the long period, if it maintains its human resource, supply of raw material, sale of products and the possibility of up gradation. Campuses of the University of the West Indies (UWI) will keep on providing necessary human resources, FPGA or other supporting hardware can be managed for US easily, consumer product related to day-to-day life will be always in demand and as far as up-gradation is concerned, we know that digital systems are always easy to upgrade.

The fifth issue is the training facility in the proposed area. The Mathworks Inc. and Xilinx Inc. have already entered a strategic exclusive alliance and joint development agreement for the system level creation of FPGA–based DSP designs (Hoimberg and Mascarin, 2000). Both companies have their own university training programmes and UWI can avail the benefits of these programmes.

3. Major Objectives

Vision here is to develop an internationally accepted incubation centre for excellence in VLSI design within the Caribbean region, which will be recognised for technological contributions, fundamental research as well as development with the help of strong academia-industry participation on a mutually rewarding basis. Mission behind this proposal is to create a sustainable infrastructure for VLSI design with the following goals:

1) To achieve high research impact through active participation of UWI faculty and students,
2) To deliver novel solutions to electronics market (consumer market in specific),
3) To encourage direct industry participation through projects and visitor programmes,
4) To create resource base, design expertise and development tools, and
5) To provide economic strength to the Caribbean as a whole.

The above said mission can be accomplished using three-step strategy i.e. by investing in good education to produce smart people, investing in research and development (R&D) to produce smart ideas and creating the right environment in which smart people can develop smart ideas.

4. Visualisation

Figure 1 represents the visualisation of the proposed VLSI Research Unit for sustainable VLSI infrastructure development in the Caribbean region.
First of all, let us have a look on the infrastructural requirements for the proposed research unit.

These requirements can be categorised as follows:
1) Electronic Design and Automation (EDA) Tools.
2) Configurable Hardware (FPGA).
3) Computing Facilities.
4) Space.
5) Utilities.

EDA or Computer Aided Design (CAD) tools are high end state of art softwares that are integral part of the VLSI design. The specific system simulator to be used is Simulink, which runs within the Matlab programming environment. Matlab is familiar to a large number of engineers and scientists, and as part of an open programming environment, provides an ideal platform for DSP system level tool development. The Matlab environment allows the DSP designer to take advantage of using familiar stimulus generation in addition to output data analysis tools. Various toolboxes and block sets of Matlab will be needed for this proposal (Pratap, 2005).

The second required EDA tool is Xilinx System Generator for Simulink software. Along with the Mathwork’s popular Simulink system-level design tools and the Xilinx CORE Generator & LogiCORE DSP algorithms, this software is the first to bridge the gap between system-level DSP design and FPGA implementation, allowing developer to easily design high-performance DSP applications in Xilinx FPGAs (Vanevenhoven, 2007). In addition to the Simulink tool, there will be requirement of logic synthesis libraries, a hardware macro generator, and place-and-route software collectively known as the Xilinx Foundation Series Software (Dick and Krikorian, 1999). Apart from these, commercial as well as academic licence of few EDA tools from Mentor Graphics, AccelChip and Cadence will also be needed.

The second infrastructural requirement is the configurable hardwares, particularly FPGAs, on which consumer products are to be developed. Xilinx has produced FPGAs that can provide world’s highest-performance programmable DSP solution, having access to millions of gates with Tera MACs per second performance (Hauk, 1998). So FPGAs for consumer applications can be obtained initially from Xilinx and at later stage from other companies like Altera or Atmel. Supporting chips like ADC and DAC etc. can be sourced from Texas Instruments, which also runs university programme. Multilayer PCB development and packaging facility will be needed to produce complete product.

Next infrastructural requirement is establishment of computing facilities. Powerful servers will be needed at VLSI Research Unit (at St. Augustine Campus) as well as nodal research centres (other UWI Campuses) along with workstations. Space for main research unit and other nodal centres is other requirement. Main unit will need more space (St. Augustine Campus has plenty of space for this in new engineering building) where as space equivalent to two normal computer labs will be sufficient for nodal centres. Last infrastructural requirement is utilities like telephone, internet access and basic facilities etc.

UWI faculty has to play very vital role in the proposed development. Almost whole of the responsibility to carry out research and development for this work will be of the faculty members of Physics, Mathematics, Computer Science and Electrical Engineering departments of all the three UWI campuses. Main research unit and nodal centres will be headed by the most experienced faculty member of the field. Various other people apart from the UWI faculty will be part of the proposed unit. These includes permanent staff having expertise in FPGA based VLSI design & EDA tools, visiting experts from industry, students and trainees. Faculty members from other institutes can also be involved in the research group to carry out specific projects and consultancy. Industry experts will also participate in projects, act like consultant, provide necessary training and will keep all the members updated. Students and trainees from all the campuses of UWI, industry and other institutes in Caribbean and worldwide will be
encouraged to be a part of this research unit.

Industries like Xilinx, Altera, Atmel, Texas Instruments, Mentor Graphics, Mathworks and Cadence should be encouraged to participate in this proposal under their university programme. These industries will be chief source of funding for the centre and will provide access to their laboratory resources for specific technology research, project developments, training programmes and student participation. There should be effective representation of industry on the steering committee. Steering committee should be made for proper functioning and for monitoring development of the entire unit. Faculty members and experts from industries nominated by Vice Chancellor of UWI should be the members of steering committee. Committee will oversight all the activities of the entire unit, will liaise with UWI and industry, and will be responsible for charting the long-term growth of the unit. Committee organisation is shown in Figure 2.

Manufacturing and marketing are the major issues that will be addressed properly for sustainable growth of the unit. As far as manufacturing is concerned, unit has to configure (design) FPGAs provided by Xilinx etc. so as to use them for specific consumer application product. Application codes will be developed through combined effort of UWI faculty, research staff, students and industry experts. Unit head will be responsible for manufacturing of end product (i.e., FPGA chips). Marketing of chips will be done with the help of Marketing and Communication Department of the UWI, Industrial links of the staff and government. Even separate marketing wing of the unit can be established and marketing experts from Economics department of UWI can be involved. It has been observed that general products producing business units located in the university departments generally cannot compete in the open marketplace but the proposed area requires very skilled manpower so ordinary industry cannot compete with the university based units. Various Indian IITs and US universities are successfully running their VLSI research units.

5. Research Methodology

Various consumer electronics applications will be modelled and simulated in the Matlab. After that, Matlab model of application will be converted into any popular Hardware Description Language (HDL) programme using Xilinx System Generator for DSP (Cigan and Lall, 2005). Then using Xilinx ISE Foundation Series software and Mentor Graphic’s Design, Verification & Test package, simulation and synthesis of the HDL model will be done. Finally after verification, consumer application will be implemented on Xilinx based FPGA and design validation will be carried out to check the performance of the designed product (Tanurhan et. al., 2006).

A block diagram of the design flow for modelling and implementation of consumer electronics product is given in Figure 3. The entire design flow is described hereafter, which is applicable to all applications and targets (along with Xilinx FPGA and custom logic devices). Within Simulink, the DSP system designer creates a model of the hardware system as well as test environment in which we have to simulate the model. The system model is capable of operating on real (i.e., double precision, floating point) or integer (i.e., quantized, fixed point binary) data types. When the model is first entered, simulation is typically performed using floating data types to verify that its theoretical performance is as desired. The internal data types are then converted to the bit true representations that will be used in the hardware implementation, and the model is re-simulated to verify its performance with quantized coefficient values and limited data bit widths, which can lead to overflow, saturation and scaling problems. User defined black boxes can also be incorporated in the modelling and elaboration process (Turney et. al., 1999).

The designer can invoke the net lister and the test bench generator as soon as the model get converted to form a realisable system in the FPGA and its performance meets specification. The net lister extracts a hierarchical representation of the model’s structure annotated with all the element parameters and signal data types. A mapper then analyses the elements in the hierarchy and creates a
VHDL [VHSIC (Very High Speed Integrated Circuit) HDL] description of the design. Where possible, the mapper uses the Xilinx CORE Generator to make hardware macros for specific design elements. When an element or its parameter values imply functionality unavailable in CORE Generator, the mapper instantiates a reference to a parameterised, synthesisable entity in a synthesis library or user supplied model.

Figure 3. Design Flow for FPGA-based Consumer Electronics Product Development

Source: Abstracted from Turney et.al. (1999)
The actual hardware entities used have additional inputs and outputs for control signals that are not evident at the level of abstraction used in Simulink. The mapper adds the necessary control ports and connects them up to control logic blocks. Each control logic block is given a default synthesizable behaviour, which may require alteration by a logic designer to achieve a working implementation. This alteration is shown in the flow through Control Design. The test bench generator is an interactive tool that runs in the Matlab environment, in which the designer captures the input stimuli and system outputs of selected simulation run for conversion to test vectors. The generator converts the captured simulation data into VHDL code that will exercise the implemented model and test its outputs against the expected results.

The Xilinx Foundation Series tools are used to synthesise the control logic and those elements for which no hardware macros exist and combine all the pieces into a single fully-realised netlist and place and route the design in an FPGA (Synplicity Inc., 2005). The outputs of this back-end process are a bit-stream file and an EDIF (Electronic Design Interchange Format) structural netlist of the hardware file annotated with timing information, which can be sent to the foundry for mass production after successful device design. This netlist can be simulated with the test vectors produced previously from system simulations to verify the performance of the completed FPGA hardware realisation.

6. Benefits

6.1 To the Caribbean and UWI

Mutual benefits to UWI and the Caribbean as a whole upon developing sustainable infrastructure like VLSI Research Unit will be as follows:

1) Due to better infrastructure, researcher of UWI and the Caribbean will able to conduct research with higher impact.
2) Due to higher level of industry interaction, upliftment of research, development, training and review is expected.
3) Caribbean will have accumulating resource base of expertise and intellectual property to generate revenue through consultancy worldwide.
4) Funding for research and development can be managed from alliance industries.
5) UWI will get support for post-graduate research programmes and Caribbean will get its own skilled manpower in the area of VLSI.

6) With the help of industry, VLSI unit will be able to produce low cost consumer electronics products for the Caribbean to strengthen its economy.

6.2 To Industry

Along with UWI and Caribbean, industries will also get benefited by the proposed development. Major benefits to the industries will be as follows:

1) Industry will get skilled manpower in the area of VLSI design, which is the biggest challenge nowadays.
2) Industry will able to work on their Strategic Research Projects driven by faculty attached to the unit through participation of students and industry.
3) Industry can drive their Short-term Development Projects which will provide access to tools and facilities available in the unit to the industry, and industry can involve faculty through consultancy.
4) Training programmes conducted by laboratory staff and/or faculty will reduce the financial burden of industry because now industry will directly get trained manpower and can save millions of dollars.
5) Industries can conduct training programmes for their employees using laboratory facilities of the unit.

7. Current Status

VLSI research laboratory has already been established in the Physics Department of UWI’s St. Augustine Campus. Laboratory is equipped with basic EDA tools, FPGA target boards and various test / measurement equipments. Department is going to establish research collaboration with electrical engineering and mathematics departments of its own campus along with physics department of Barbados campus. Very soon Jamaica campus will be involved in this pilot project but there is still a need of bringing physics, mathematics, computer science and electrical engineering departments of all the UWI campuses under a single system administration setup. As far as the industries are concerned, Mathworks, Cadence and Xilinx are already involved somehow with UWI under university programme. Other suggested industries have to be involved in this project.

As far as existing research and development activities in this area are concerned, plenty of faculty
members from St. Augustine campus are involved in so called Electronic Systems Group. This group conducts research and collaborative work in the design of reconfigurable logic systems using the ever-increasing family of static RAM base programmable logic devices such as the FPGA and the Complex Programmable Logic Device (CPLD). Two research projects in the area of “VLSI implementation of DSP algorithms” are also in progress at physics department of the same campus.

St. Augustine campus is currently offering Bachelor of Science (BSc) in Electrical and Computer Engineering programme with electives in Electronic Systems and Master of Applied Science in Electrical and Computer Engineering (MASc) programme with majors in Electronic Systems. Department’s electronic systems programme emphasises analog and digital electronics design using state-of-the-art simulation and CAD tools as well as cutting edge CPLD and FPGA technology. The Department of Physics is also planning to start its Master in Physics (MPhys) programme with major in Digital System Design / VLSI Design. Few students are working here in the area of VLSI design for their MPhil and PhD programmes.

8. Conclusion
In this paper, a proposal on the development of sustainable VLSI infrastructure for the Caribbean countries is presented with the objective to make Caribbean a major VLSI design testing and application development destination globally and to catalyse an increase in Caribbean share in the global market through consumer electronics products apart from petro-products. The basic philosophy behind the programme is for the government to play the role of catalyst and infrastructure provider.

The key ingredients of the government inputs for this area are: investing in good education to produce smart people, investing in R&D to produce smart ideas and creating the right environment in which smart people can develop smart ideas. Initial setup cost of the suggested unit will be around USD 0.5 million only and recurring annual expenses can be managed from annual membership from each industry, consultancy and products development. Basic infrastructure and manpower for this proposal can be easily arranged from all the three campuses of the UWI. Funding, training and high-end research facilities can be managed from industrial collaboration. The proposed VLSI infrastructure is sustainable and can boost-up the economy of the Caribbean region.

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