1. INTRODUCTION TO TRAINING ESTABLISHMENT

1.1. Overview

ParaQum Technologies, a startup with a very short history is a fast growing electronic product developing company specialized in several niche areas of electronics such as Re-configurable Digital Systems, Semiconductor Intellectual Property (IP) cores and Embedded Systems. Under the leadership of Dr. Ajith Pasquel as the Chief Executive Officer, the company is fast growing in its fields of specialization. The startup which is been supported by the “Facilitation Center for Advanced Electronic Design” of the Department of Electronic and Telecommunication Engineering, University of Moratuwa has grown to a fully functional startup company.

Figure 1.1: Company Logo

ParaQum which started under the name GalaxyCores (Pvt) Ltd specializing in the field of developing semiconductor intellectual property cores has now being expanded to fields of developing products based on IP cores and embedded systems on customer request. The main product of the company, Intellectual Property cores are digital designs applicable for both Application Specific Integrated Circuits (ASIC) and Reconfigurable Digital Platforms of Field Programmable Gates Arrays (FPGA).

The flagship product of the company is an FPGA Intellectual Property core of a High Efficiency Video Coding (HEVC) Decoder which is capable of decoding 4K resolution (3840x2160) video at a frame rate of 30 frames per second (fps). In addition to the flagship product, ParaQum also provides design services to several foreign clients in the fields of FPGA prototyping, RTL verification and software tool chain development and embedded systems development. The company recently joined a project with a US based silicon valley company developing computer processors expanding its limits. In addition to that, the company is developing embedded products from specifications for a US based broadcast equipment manufacturing company.

The work force of the company which was started with only four fresh graduates about a year ago has now been expanded to eight and recruited 12 more fresh graduates this year. It operates from its office at No. 21, Seibel Avenue, Colombo 05 which is equipped with lot of equipment required for electronic product development. The company intends to launch their own line of products including semiconductor IP cores and electronic products and systems

1.2. History and Current Situation

The foundation to the company was laid by the formation of a “Special Interest Group” (SIG) on Reconfigurable Digital Systems by several enthusiastic undergraduates in 2012 at the Department of Electronic and Telecommunication Engineering, University of Moratuwa. The formation of the startup was an idea brought up at the SIG to pursue commercial prospects of electronic related research and development carried out at the department.

The company started its operations with four fresh graduates in March 2014 under the name “GalaxyCores (Pvt) Ltd” with the patronage of the CEO Dr. Ajith Pasquel, the head of Department of Electronic and Telecommunication Engineering.

In October 2014, the company opened its office at No. 21, Seibel Avenue, Colombo 05 to create an attractive environment conducive for working. Within a short period of one year, the company work force has grown from four fresh graduates to eight. Within a short period of 7 months it grew to a state from which it can accommodate 6 interns from October last year till April 2015 and provide them with a great training experience. It is further expanding its work force by recruiting 12 more graduates from the passing out batch.

Initially the company started with its flagship product, an FPGA Intellectual Property Core for High Efficiency Video Coder Decoder capable of decoding 4K resolution video at 30 frames per second. Later the company was able to find foreign clients especially from United States and diversify its range of products and services. It recently came into an agreement with a Silicon Valley company for a massively parallel computer processor development project. It’s rapidly progressing into the field of embedded systems designing with a US based broadcast equipment manufacturing company providing necessary support.

The company has a vibrant group of young engineers ready to take challenges in the industry and a friendly environment where everybody can give their best in their projects. Therefore it will be achieving its goal of launching its own line of products including semiconductor IP’s and electronic products and systems and being a leading company in the electronic and semiconductor space in near future.

1.3. Functions and Fields of Specialization

ParaQum Technologies was formed aiming to specialize in the field of developing Intellectual Property Cores which is a niche area of electronics. Later it expanded its wings to the fields of developing products based on IP cores as both Reconfigurable Digital platforms (FPGA) and Application Specific Integrated Circuits (ASIC). The following is a brief listing of fields of specialization of ParaQum Technologies,

- Developing Semiconductor Intellectual Property Cores
- Developing products based on IP cores
- Developing semiconductor IP cores and products on field of networking
- Developing Embedded systems from specifications
- Broadcasting equipment manufacturing

1.4. Organizational Structure

The company structure is organized under three basic layers as the chief executive officer (CEO) Dr. Ajith Pasquel residing in the top and the board of directors comprising of three directors in the second layer and the engineers in the third layer. The lower layer is again sub divided as systems architects and electronic engineers. System Architects include software architects, hardware architects and embedded systems architects leading projects groups in their respective fields. Having resource people with a vast knowledge in the top two layers, the projects groups have the luxury of consulting the top layers for the issues that they face in design processes. There is an environment created where directors also give their knowledge and expertise in projects joining project groups when required.

Although there is a hierarchy like this, there is no barrier to discuss anything with anybody inside the company. All the employees are considered the same and anybody can raise his question with no hesitation at all. This has created a very friendly working environment which helps a lot in bringing out the best of everybody.

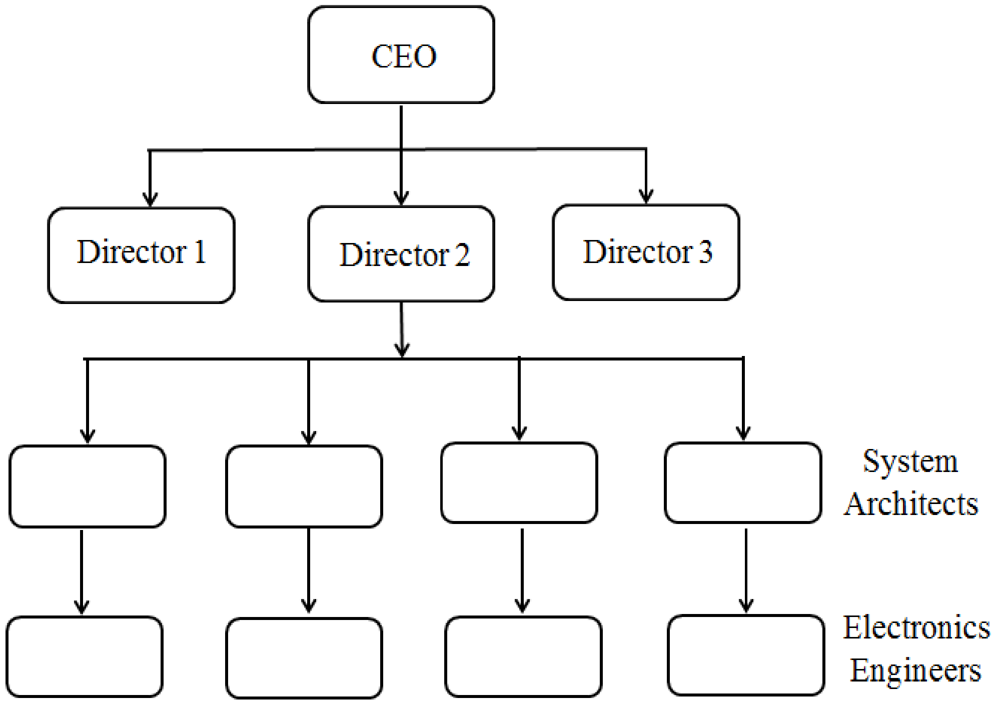

Figure 1.2 : Organizational Structure

1.5. Company Performance

1.5.1. Strengths and Achievements

As a high end technology product designing company the biggest asset and the strength of ParaQum is its vibrant workforce. Currently it has a vibrant work force of 8 young engineers from Department of Electronic and Telecommunication, University of Moratuwa. It has already recruited another 12 from the same department and they will be joining the company in near future. In addition the company was able to provide a great training experience for six undergraduates for 6 months. This rapid expansion shows the amount of success the company has been able to achieve within a short span of about one year.

With the latest technology ParaQum is the only or one of the very few companies in the country working on cutting edge technology in the field of Electronics and digital systems designing. The talents of the fresh graduates who have the thirst to learn and an appetite to take challenges, enables the company to go for products using cutting edge technology. The fast learning ability of fresh graduates helps succeeding such projects.

The engineers at ParaQum are very much passionate in their fields. This is evident from the fact that their flagship product the HEVC decoder is the final year project of the four engineers working on the project. They have selected it at the university because of their passion towards that field and now they are very happy about the fact that they have got the chance to extend their work much beyond the final year project. This has been a key to the success of the company over the last year and this has been a point of attraction for fresh graduates to join ParaQum.

Another victory of the company is the partnership agreement they have come up with a Silicon Valley company developing massively parallel processor chips. It is the first time a Sri Lankan company has joined such a project and it has shown the talent our young engineers have in such technologically advanced fields.

The expanding client list is also a victory of the company and it has been able to succeed in attracting more and more new projects from foreign companies in their fields of specialization.

The friendly environment inside the company where the opinions of all including that of interns are given a respect is also a strength of the company. And the fact that directors also working at times in project groups with no difference makes it such a friendly atmosphere. This environment helps taking best out of the employees.

The visionary leadership of the company chief executive officer (CEO) Dr. Ajith Pasquel with his expertise in the field of electronics is a huge advantage for the company. His advices and consultancy in projects helps young relatively inexperienced engineers very much.

The help given by the Facilitation Center for Advanced Electronic Design of the Department of Electronic and Telecommunication Engineering, University of Moratuwa is also a big strength to the success of the company. The startup company is now making moves to stand on its own by establishing its own work spaces and increasing resources.

Stepping into the Embedded systems market will also add to the strength of the company because then the company has the variety in their products reducing the over dependency on a certain field.

1.5.2. Weaknesses, threats and areas to improve

There are few weaknesses I have to point out about the company as well. Lack of our own products in the market is a big issue in making a good trademark in the industry. The only product of their own is the flagship product, the HEVC decoder is yet to be launched at the market. The launch of this product will ease out that issue to a certain level. But the company has to strive hard to put more products of their own to the market to reduce the threat from rival companies.

The other issue I have to figure out is the over dependency on several foreign clients. This gives them the bargaining advantage in buying services from the company. And it also comes with a big risk of the clients playing a big role in decision making process of the company.

Another drawback I see is the lack of diversification of products in the company. The company has to expand its wings to more fields otherwise a competitor gets the chance to suppress the company using their market share and capital. If the company focuses on only one or two niche fields then it has to make plans to keep at least two such fields and bring the company to a situation where a totally failure in one niche market would not affect the company’s stability because the other niche market can give the necessary stability.

Lack of experienced employees for some fields is also a barrier to the fast growth of the company. There are situations where the whole project group grounds to a standstill in certain technical issues. It would be of great help for the team if someone experienced is there to help the team in such situations.

Lack of management and marketing expertise is also a little drawback to the progress of the company because currently all the business negotiations are done by engineers themselves and this gives advantage to the clients at times. I believe marketing is an area the company should focus on immediately because they can set more value to their products and services by having a better marketing strategy. Currently the clients are been found through contacts and there is no marketing strategy to attract customers. But to develop further the company has to develop a good marketing strategy that can attract clients. They should build up a marketing strategy that clients will come to the company rather than the company seeking clients. Although the management is not a difficult task at present with its startup nature, it will have to improve on it when the company grows big.

1.5.3. Opportunities and Profitability

ParaQum being the first company that involves directly in developing semiconductor intellectual property cores in the country has a great opportunity to attract passionate engineers to the company because they feel that this is the only place where they can excel in their passion. The projects carried out at ParaQum require a high level of expertise and talent by the engineers. Therefore attracting talented people for projects is a must for its success. Having this opportunity to attract such passionate engineers will definitely help its success.

It has a big advantage in the fact that the Dr. Ajith Pasquel who is a very reputed person in the field being the CEO. Foreign and local clients can keep trust on him in investing on projects with ParaQum. The company can make use of this advantage to get more challenging projects from their clients. The advices on both project management and technological aspects from the CEO are of high advantage to the developers. This also becomes a decisive factor in the success of the projects.

Recently ParaQum stepped into the embedded systems market which allows it to cater for local clients. This is a good opportunity for the company to expand its client network locally and achieving some popularity in the local market. And the fact that the demand for embedded systems solutions is high in local market is a good area it can focus on in addition to developing IP cores and related products. This is a profitable field and it is evident from the fact that there are fast expanding embedded systems developers in the country. ParaQum can compete with any of them with ease with its human resources and cutting edge technology.

The profitability of the projects carried out by the company will increase with time because first few projects required heavy investments on tools such as high frequency oscilloscopes, power supplies, multi meters, signal generators, server computers, software tools and etc. Once those resources are obtained after investing for first few projects they can be used for other projects without much of new investments. This will increase the profitability of future projects of the company.

The basis set by the company over the last year or so is very strong and the company can thrive on it. They have won a good reputation especially through the partnership agreement they came up with a Silicon Valley processor developer. This reputation will earn them more projects on that field especially from foreign market.

1.6. Influence on Sri Lankan Economy and Society

The electronics industry in Sri Lanka has been lagging behind in last few decades creating a big problem for graduates from Department of Electronic and Telecommunication Engineering to find employment opportunities in their field of interest. This became a cause for brain drain as well. ParaQum Technologies brings solution to this giving them the chance to work on their passionate fields staying in the country.

The company was started with the intention of pursuing commercial prospects of research and development projects carried out in electronics field at the University of Moratuwa. This has been a factor that most of the intellectual society had been demanding for a long period of time to improve the quality of research and development projects carried out at the university. ParaQum has succeeded in this aspect because it has been able to take few final year research projects of undergraduates to commercial level in a very short period. It has also offered several final year project ideas with necessary sponsorship also to enhance this flow. This is a great service to the undergraduates and the university community.

The company is also expanding its wings to give a better service to the society through various means. Sponsorship it provided to Expose Forum of the University of Moratuwa in 2015 can be cited as one such example.

ParaQum is always trying to gasp latest technologies to improve their products. This is a good opportunity for Sri Lankan engineers and other local industries to adapt to new technologies.

The company has a prime objective of encouraging most enthusiastic and brightest electronic undergraduates of the country and giving them the opportunity to make their mark in the industry and it has been successful in doing so over the last year.

ParaQum has a long term vision to bring glory to the country by becoming a leader in electronic and semiconductor space. In doing so it can increase the reputation of the country as well as strengthen the economy bringing more and more foreign exchange while keeping the brightest youth within the country.

2. TRAINING EXPERIENCE

2.1. Introduction

I was privileged to be involved in three projects in my internship playing a key role in each of the project. The fact that I spent 25 weeks (4 weeks more than the stipulated internship program) helped me in finding time for three projects. Two of those projects were focused on developing embedded systems while the other was a FPGA based RTL (Register Transistor Logic) project. The following is the listing of the main projects I was involved with the name of the supervisor and a rough estimate of time spent on each of them.

- Analog to SDI (Serial Digital Interface) video Format Converter
    - Supervisors:
        - Mr. Kalana De Silva, Associate System Architect
        - Mr. Hasanka Sandujith, ElectronicEngineer
    - Time spent: 14 weeks
- Analog to HDMI (High Definition Media Interface) video Format Converter
    - Supervisors:
        - Mr. Kalana De Silva, Associate System Architect
        - Mr. Hasanka Sandujith, Electronic Engineer
    - Time spent: 4 weeks
- HDMI Transmitter Module for Zed Board (FPGA project)
    - Supervisor: Mr. Kalana De Silva, Associate System Architect
    - Time spent: 7 weeks

Through these projects I was able to get hands on experience in electronic product manufacturing process from specifications to the final product including testing and debugging as well as providing firmware upgrades after the product was delivered. It includes both hardware and firmware design and development. Through the FPGA product I went through both implementation and simulation flows in digital design using Verilog hardware descriptive language. Since all three projects were focused on video processing, I was able to gather a good knowledge on analog and digital video formats, their synchronization pulses, standards on high speed digital data and their applicability in industry.

In addition to the experience gathered by involving in projects, we were given a good knowledge on digital systems design in industry level by workshops arranged by the company. Those workshops covered familiarizing with vivado development environment, designing with Verilog, implementation and simulation flows and procedures and good practices in digital designing. Associate System Architects Mr. Kalana De Silva and Mr. Geethan Karunaratne worked hard to teach the subject giving examples from projects that are been by the company.

There is a set of coding guidelines followed in the company which makes all the codes readable to other members of the development team. We were given templates and instructions on following them. Getting used to these patterns helped immensely in reuse of codes of other projects in my FPGA project in certain occasions rather than writing them from the scratch.

In addition to the technological knowledge and experience, we were trained to follow company procedures such as using an online repository to save all the codes and progress frequently (on daily basis). The open source software “Source Tree” was used for managing the repository and I received valuable instructions on getting used to using it. This would be of great use even in our final year project since it keeps a log of all the development we make in the design including the deviations we make to the flow and it also allows the user to roll back to an older version at any time.

Project management and team work through “ASANA” platform was introduced and used in all the projects. Tasks were allocated to interns using this platform and we got used to it in a short time. This proved a very effective way of organizing and coordinating a project and effectively managing time in a project. Getting used to it will surely be a big advantage for my future projects.

In addition to the projects and technological knowledge, we also got the chance to engage in lot of fun activities and events such as trips and parties to ease out the stress of working in advanced projects. Everybody in the staff was like intimate friends in those events and made an enjoyable atmosphere.

2.2. Projects

2.2.1. Analog to SDI Video Format Converter

2.2.1.1. Project Overview

Video Format Converter was a spec to product project for Osprey Incorporation in USA. They had sent the specifications for a video converter which can take analog video of different types/formats and convert them to SDI video which is the format mostly used in broadcasting industry.

According to the specifications, the device should be able to take inputs of three basic analog video types,

1. Composite video (CVBS) - All the video components combined in a single channel. One line carries the modulated carrier.
2. S-video (Y/C) – Carries video in two synchronized signal and ground pairs of channels as one pair for luma or the luminance (Y component) and the other for chroma or the chrominance (colour component).
3. Component Video (YPbPr 4:2:2) – Carries video in three separate synchronized channels as one for luma (Y), one for the difference between luma blue (Pb) and the other for the difference between luma and red (Pr).

The device should have three input channels taken via three BNC connectors to facilitate all these three types. The output is also connected through BNC connectors because they are the very popular in broadcasting industry.

Figure 2.1: A BNC connector used as input and output jacks

Within these types there are a lot of video formats that have to be processed.

- Composite (CVBS)
    - PAL (625I)
    - NTSC (525I)
- S video (Y/C)
    - PAL (625I)
    - NTSC (525I)
- Component (YPbPr 4:2:2)
    - PAL – component
    - NTSC – component
    - 720P 50 Hz
    - 720P 60 Hz
    - 1080I 50 Hz
    - 1080I 60 Hz
    - 1080P 30 Hz
    - 1080P 25 Hz
    - 1080P 24 Hz

Initially the design was made to use 8 switches for selecting the input format and type manually by the user. But later client had requested to develop the product to automatically detect input formats as much as possible and reduce the number of switches. Therefore the product was designed to automatically detect most of the input video formats and use only 3 switches for selecting between formats that cannot be automatically detected.

The product had two versions in which one was with audio and the other without audio. The version with audio required to take both balanced analog audio and unbalanced audio inputs and digitize it and embedded it with SDI. Therefore two audio input jacks were added and a switch was used to select between balanced and unbalanced input audio.

The client strictly wanted the device to be working on USB power hoping to keep it as a competitive advantage over their rival companies. The USB jack in a PC gives only up to 500-mA current without switching off the port. This imposed a big constraint to the design in term of power consumption. Therefore we paid special attention on power consumption in selecting components as well as in settings internal parameters such as bias current in developing firmware.

Figure 2.2 : Finished Product

2.2.1.2. Initial Planning and Hardware Design

The initial plan of the product had been developed to a considerable level when I was assigned for the project. The team had decided to use ADV7181C IC of Analog Devices Inc. as the analog to digital converter in the analog front end and TW6872 IC of Intersil Inc. for the task of converting raw digital video data to SDI video. The output of the analog to digital converter should comply with CEA standards for uncompressed high speed digital data and BT.656 standards for it to be given as input to TW6872.

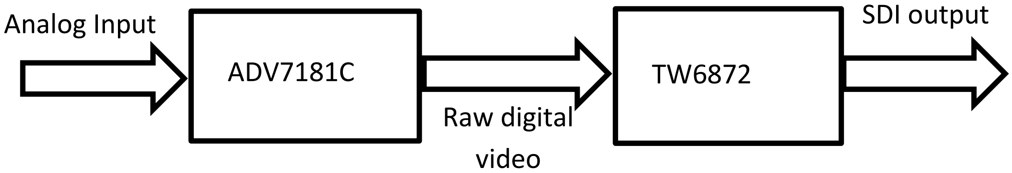

Figure 2.3 : Big picture of the Analog to SDI Video Format Converter

An Atmel 328 was selected as the controller of the device which configures the above two IC's to different input formats. The firmware for the device has to be run in the Atmel 328 and configure other IC's using I2C protocol.

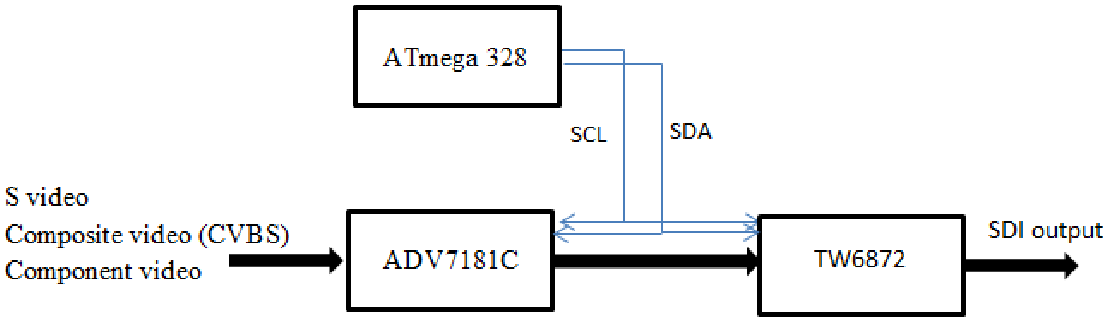

Figure 2.4: Higher Level Block Diagram

Since the client had given a small box of the size of a cigarette box as the enclosure to which the device had to be fit in, the circuit required to be very small in area. Therefore the circuit designing team decided to design the circuit with six layers.

An evaluation board containing ADV7181C was supplied for evaluating the IC but it had only a component output through ADV7341 and a HDMI output driven through AD9889B. An evaluation board containing TW6872 was also supplied for the designing process. Those two boards and their evaluation software were installed after a lot of hard work. The evaluation board containing ADV781C can be installed only in windows XP environments and therefore I had to install it in a windows XP virtual machine. Finding the device drivers for them was also a difficult task.

After reading the datasheets of ADV7181C and TW6872 and their design support files, we tested different configurations for those two ICs and figured out that we require a 20-line connection between the two IC's in the circuit. Similar kind of testing was done to arrive at decisions required for the hardware design process.

Schematic and layout designing was assigned to a group of two engineers well versed in the field. They got the collaboration of the whole project group in designing the schematic but the routing was done by the two alone. Schematic design process was a discussion type of a process where all the group members put in their ideas and views on certain factors such as keeping layers with high speed signals in between two ground layers. All the design guide lines given in the data sheets were also followed. For example, the 20-line connection between ADV7181C and TW6872 were length matched (made equal in length) following a guideline given in the datasheet for TW6872. Subsequently after lot of reading and discussions, the schematic was finalized and sent to for routing which was an extremely difficult task due to the very small size and the complexity of the schematic. Once the layouts were done, it was sent to a foreign manufacturer and got 3 units of the first prototype manufactured in about two weeks.

Then started the testing and debugging process to identify errors and short comings of the design. This process is explained in more detail later in this chapter. After finding the bugs, both firmware and small hardware changes were done on the same prototype and large hardware changes were made in the new design for the second prototype. Then designing schematics and routing were done again and once finished were sent for the foreign manufacturer to get the second prototype manufactured. Similar procedures were followed to get the third and final prototype manufactured also.

2.2.1.3. Firmware Development

The design includes two video processing IC's ADV7181C and TW6872 that have to be configured with relevant register values according to the input video format and output format. This is done by the programmable Atmel 328 microprocessor. Firmware should be developed to run in Atmel 328 microprocessor and control other integrated circuits according to the input and output video formats. The task of firmware development for the whole device as entrusted on me and Mr. Kasun Athukorala who joined the project on part time while working on several other projects at the company. Therefore I got to handle a big responsibility and risk.

Firmware development started with developing scripts for the two evaluation boards containing ADV7181C and TW6872. Installing ADV7181C evaluation board in PC was a difficult task because it can be installed only in windows XP platform. The fact that this wasn't stated in the device support files or any other source made me waste some time finding reasons for not installing properly on windows 8. Somehow I got it installed in a windows XP virtual machine and got it working. There were several design sample scripts given for the ADV7181C evaluation board for converting analog video to 8 bit and 12 bit versions of component video using the ADV7341 encoder IC and to HDMI video using AD9889B HDMI transmitter IC. But the new design had only 20 and 10 line connections in between the two IC's where as there are only 12 and 8 line connections routed between ADV7181C and AD9889B in the evaluation board. Therefore only 20 line and 10 line connections between ADV7181C and ADV7341 were used for developing scripts.

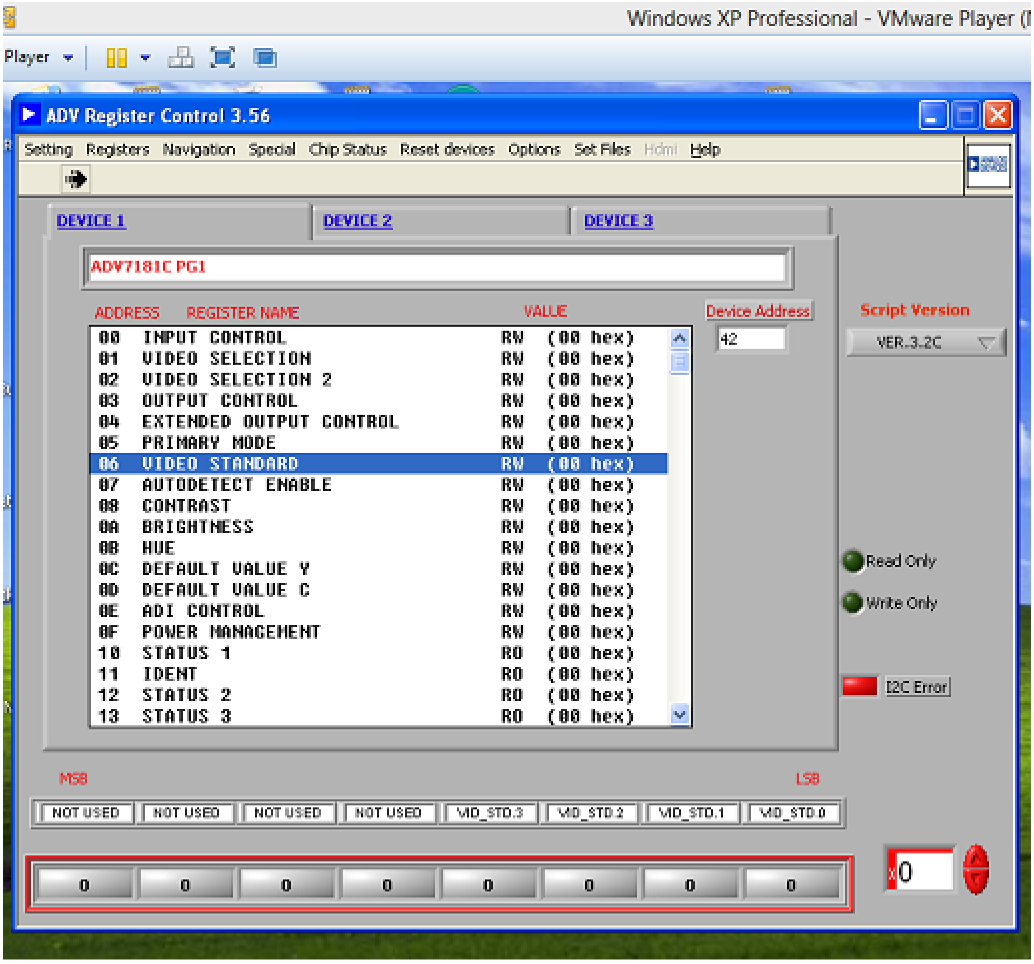

Figure 2.5: Testing ADV7181C in Evaluation Board using ADV Register Control Software

There are registers starting from 0x00 to 0xFC, all together 252 registers. I read the whole data sheet and support documents several times and figured out some important registers on which the output video would depend. But changing them to calculated and recommended values didn't give a visible output at the beginning. Lots of combinations were tested for important register values of both IC's but no visible output was taken for more than a week.

After about two weeks of rigorous attempting, I was able to get the expected output for composite video. I was able to increase the quality of the output video by further adjusting those register values set in the two IC's using the GUI provided with the evaluation board. Then I started testing for other video formats for which there were video sources in the company. Several video formats were not available in any of the source devices available at the company. I figured out several registers that directly affect the visible output of the device. Those registers are responsible for the analog front end voltage threshold, bias current, primary mode, video standards, power management, etc. I tried changing above registers to different values according to calculations and finally got the output. One by one, I was able to get the scripts done for each format. Then I demonstrated the outputs in the monthly evaluation meeting and started the work on SDI transmitter side.

The evaluation board for this IC is complex and has a FPGA also for pattern generation. But developing scripts for that board was easier because its sample code worked. After finalizing the scripts for both boards I started writing mikroC codes including these register settings in it. MikorC pro for AVR software was used for this.

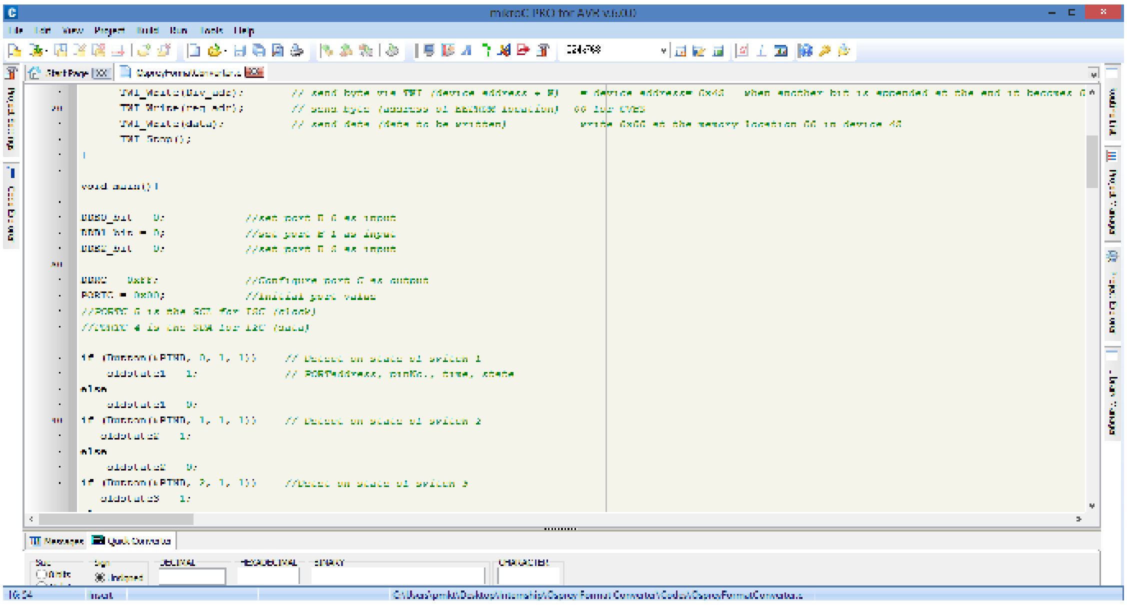

Figure 2.6: Developing codes on MikroC pro for AVR

But later it was later felt that Arduino platform would be the easiest to code this and switched to Arduino IDE because it had easy compatibility with avrdude software used to program the atmel microprocessor.

But we did not have a system to test these two IC's in the same platform until the first prototype was received after manufacturing. Therefore we kept the register values for formats that cannot be tested similar to closest format testable. For example, since the 1080I 60 Hz video source devices were not available in the company, I kept the most of the register values of 1080I 60 Hz format similar to that of 1080I 50 Hz format.

The planned method for programming didn't work for the first prototype. Therefore we found out other methods of programming the device. Finally we were able to program the microprocessor using a USBasp AVR programmer using the AVRdude and a modified configuration file. The configuration file was altered to give the programmer the ability to program Atmel 328. The programmer could not program Atmel 328 although it can program Atmel 328P due to the configuration file. By altering this file we can make it program Atmel 328 also.

To meet the customer's requirement of operating with USB power we had to save every micro Ampere of the current consumption. I made use of the power management register 0x3A and TTL (Transistor-transistor logic) control register 0x3C for this purpose. The ADV7181C IC has two processing cores as component processor (CP) and Standard Definition processor (SDP) of which only one works at a time. In order to minimize power consumption, the component processor is put to a power down status while SDP is processing the video. Similar thing happens for CP also. When SDP is functioning, CP is put to a power down status.

An ADC (Analog to Digital Converter) consumes about 40 mA in normal operation. Therefore a lot of power can be saved by switching off ADCs that do not work in certain formats. These features were implemented in firmware to reduce power consumption to keep the maximum current below 500-mA limit of the USB port.

The Atmel microprocessor keeps reading the input of the switches in every loop and checks whether they are different from that of the previous loop. If it sees a change the micro controller identifies the format to which the switches are assigned in the new switch configuration. Then the micro controller sends the I2C (Inter Integrated Circuit) commands relevant to that format.

I2C communication was first tested between an Arduino board and an IC in the evaluation board. It was used to check whether the I2C read and write functions were correct. After that those functions were added to the main code. Although it was planned to implement one read function for both IC's and one write function to all IC's it was later seen that the address conventions of the two IC's are different from each other and required two different pairs of functions.

Once all the settings in scripts were converted to C code and added as sequences of commands, the program exceeded the ROM limit making it unable to compile. Therefore I combined sets of codes by comparing similar settings in different formats of video. This way I was able to solve the issue of ROM space not being enough for the program.

Firmware development faced a big challenge when the client requested the product to be automatically detecting input video formats without using switches to input the video format manually. After reading datasheets we found that there is a register that get automatically updated with the block length of the video. This could be used to implement auto detection of input video types. But there are several video types with overlapping block length ranges. Therefore there was no other option than allocating a few switches to select them. Somehow most of the video formats are automatically detected by the device. I made a custom algorithm for the purpose of auto detecting input video formats.

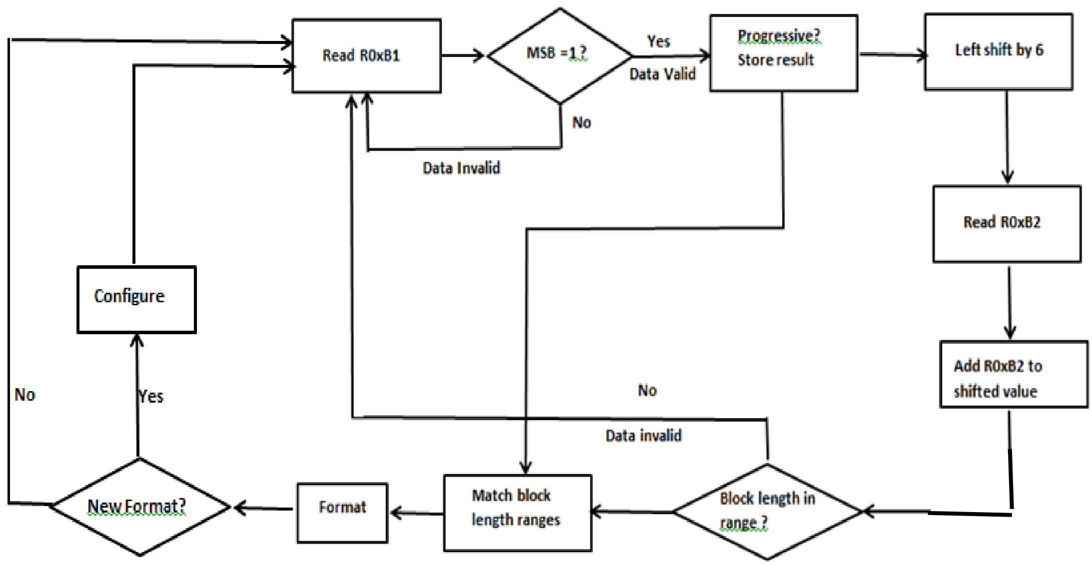

Figure 2.7: Block Diagram of the auto detection algorithm

Auto detection part of the code is only executed when the switches are set for auto detection. When the switches are set for auto detection of the input video type, the atmel 328 keeps reading the block length of the input video type in each iteration of the main loop and checks whether it is valid. If it is valid then it checks whether the input video is progressive or interlaced and stores that information to be used later. Then it calculates the block length by reading two registers and appropriately manipulating those values. Then it checks to which block length range does the calculated block length belongs to and selects the video format. It uses the information whether the video is progressive or interlaced in this process. If video format found in this method is different from the current video format to which the IC's are programmed to, it updates the current program to the new format and sends relevant I2C commands to other IC's.

The switch changers would have been made smoother and faster detection would have been possible if interrupts were activated. But unfortunately interrupts and I2C libraries cannot be activated simultaneously for Atmel 328. Therefore interrupts were not added and delay times were reduced to avoid any inconvenience faced by the user.

After programming the atmel and testing it was seen that the program gets stuck in the middle of I2C communications at times. Although such stalls are rare, we needed to avoid them to increase the quality of the product and give a good user experience. So we implemented a watchdog timer to keep watch on whether the program gets stuck and if it happens then to reset the program immediately. The watchdog timer counts the time since last watch dog reset was executed in the program. If the watchdog timer limit is exceeded in between two watch dog timer resets, it resets the whole microcontroller program by hardware. This is used to reset the program whenever the program gets stuck. Initially we set the watchdog timer to 4 seconds and little by little brought it down to one second to improve the response time if the program gets stuck.

GitHub online repository was used to store progress of C codes using the source tree open source software. But using this repository management software, all the changes made to the code can be traced back in time very easily. Therefore I was able to make changes to the code and add new features without having a fear of losing the current progress.

2.2.1.4. Testing and Debugging

When the first prototype was arrived from the manufacturer we checked the circuit for visual faults. In this step we found that two resisters of the circuit have interchanged and were changed before giving power. If we had skipped visual inspection and given power straight away, it would have surely damaged some components of the circuit. Then proceeded to give power and checked power levels at crucial positions of the circuit.

We had planned to program the device with USBasp programmer with AVRdude platform but it wasn't successful. The device ID didn't match with that in the configuration file. After a bit of search, it was identified that the USBasp cannot program Atmega 328 microprocessor although it could program the Atmega 328P. The solution we came up with was to hack the "avrdude.conf" file in the Arduino installation folder. By this we added the configurations required for programming Atmega 328 also into the configuration file. Then the problem with device address of the IC was solved. But the programming was not successful even after doing that. After more investigation we found that the speed of programming is too much for the device and decided to slow it down by fixing the "slow rate programming" jumper of the programmer. Then the programming was successful and verified.

```
#------------------------------------------------------------
# ATmega328P
#------------------------------------------------------------

part
    id              = "m328p";
    desc            = "ATMEGA328P";
    has_debugwire   = yes;
    flash_instr     = 0xB6, 0x01, 0x11;
    eeprom_instr    = 0xBD, 0xF2, 0xBD, 0xE1, 0xBB, 0xCF, 0xB4, 0x00,
              0xBE, 0x01, 0xB6, 0x01, 0xBC, 0x00, 0xBB, 0xBF,
              0x99, 0xF9, 0xBB, 0xAF;
    stk500_devcode  = 0x86;
    # avr910_devcode    = 0x;
    signature       = 0x1e 0x95 0x0F;
    pagel           = 0xd7;
    bs2             = 0xc2;
    chip_erase_delay    = 9000;
    pgm_enable = "1 0 1 0 1 1 0 0 0 1 0 1 0 0 1 1",
        "x x x x x x x x x x x x x x x x";

    chip_erase = "1 0 1 0 1 1 0 0 1 0 0 x x x x x",
        "x x x x x x x x x x x x x x x x";

    timeout = 200;
    stabdelay    = 100;
    cmdexedelay = 25;
    synchloops   = 32;
```

Figure 2.8: Changing the configuration file of avrdude

```
C:\Windows\system32\cmd.exe
D:\PRograms\arduino-1.5.4\hardware\tools\avr\bin>avrdude -CD:\PRograms\arduino-1.5.4/hardware/tools/avr/etc/avrdude.conf -v -v -v -v -patmega328 -cusbasp -Pusb
-Uflash:w:C:\Users\pmkt\AppData\Local\Temp\build4875164400679600270.tmp/internal_pattern_gen_from_internal_atmel.cpp.hex:i
```

Figure 2.9: Programming the microcontroller using the console

There wasn't any power fault and the programming was also successful but the device didn't work at all. There wasn't any clue to which one was having the fault. It could have been hardware, firmware or both. Therefore we started normal testing and debugging sequence that went on for more than two weeks.

Testing starts with visual inspection of the whole circuit to see whether it matches exactly with the schematic and layout. If there isn't any fault, then several crucial points are selected and the device is powered up. Then the voltages at those crucial points are measured. If all of those points are having the required voltage level, then the debugging has to go for more complex solutions.

In this case, we extended the I2C lines of the device by tapping them from outside. The tapped I2C lines were observed using a digital oscilloscope. After setting triggers we were able to see a single transaction at a time and we read the digital values and identified that the acknowledgements were not sent. Something was wrong with I2C communication and we began investigating into it.

After some testing and referring back to datasheets it was found that the address convention of the two IC's are different and that fact is not mentioned clearly in datasheets. For ADV7181C, the real address should be transmitted with a separate bit to say whether it is a write operation or a read operation. But for the TW6872 IC, the address should be appended with the last bit to say whether it is a write operation or a read operation before transmitting the address. Once that fault was corrected the communications were acknowledged.

Then we used the tapped I2C line to read register values via an Arduino which uses serial print to show the read values in the monitor. But here the Arduino works on 5 V power domain while our new circuit works on 3.3 V domain. A resister divisor was used to avoid damages to the circuit from 5 V power domain in the other circuit. Using the Arduino we were able to write and read registers in the IC's of the device to check whether the communications with the internal IC in the device is working properly. In certain occasions such communications had failed and written wrong values to registers. I noted down them and added read back functionality to them to read back the values after writing and compare with the correct value to see whether the correct value has been written. If an error is encountered another write operation is instructed.

We also changed fuse values of the atmel 328 to match it with the clock in the circuit and to set the I2C clock frequency to 400 kHz by using the avrdude on console.

After some time we tapped the I2C lines of the two evaluation boards and made a single I2C network. To avoid the clash (Multi master clash) between the internal atmel and the external Arduino, a "do nothing" code with I2C initialization was put to the internal atmel to keep it busy without sending any I2C signals but holding the SDA and SCL high to stay without obstructing the communications between other IC's. Then the I2C addresses of the IC's in the evaluation boards were changed by using different methods to avoid multi slave issue. The Address of ADV7181C can be changed from 21 to 20 by grounding a certain pin. Such a procedure was adapted to solve the multi slave issue of the TW6872 also.

I also observed that the I2C signal lines are prone to noise. When the extended I2C network spread across 50-Hz power lines, communications were obstructed most of the time.

This method was done to read and write registers using the GUI's given with their evaluation boards. It makes the changing register values an easy task and lets us try different combinations.

But the device didn't give any video output amid all these changes we made to firmware. Then we went to the microwave lab at the University of Moratuwa to test the SDI output side of the device with a spectroscope and a high speed oscilloscope. The spectroscope showed that the device is outputting some sort of a high speed signal with frequency component very much similar to expected SDI signal frequencies but the sampling frequency of any of the oscilloscopes were not enough to see what the actual output signal was.

For further analyzing the output side of the circuit an SDI transmitter IC of the circuit was programmed to give its internal pattern and it worked. There we realized that the output side of the circuit is working and the problem is in either the input side or in the link between the two sides. Further analyzing the two IC's functionalities we found a register change out of the recommended value for that register in TW6872 giving an output video. But the previous value of the register was set by a sample code provided with the evaluation bard from Intersil. The sample code has had an unidentified error. We informed the Intersil about the fault in that sample code.

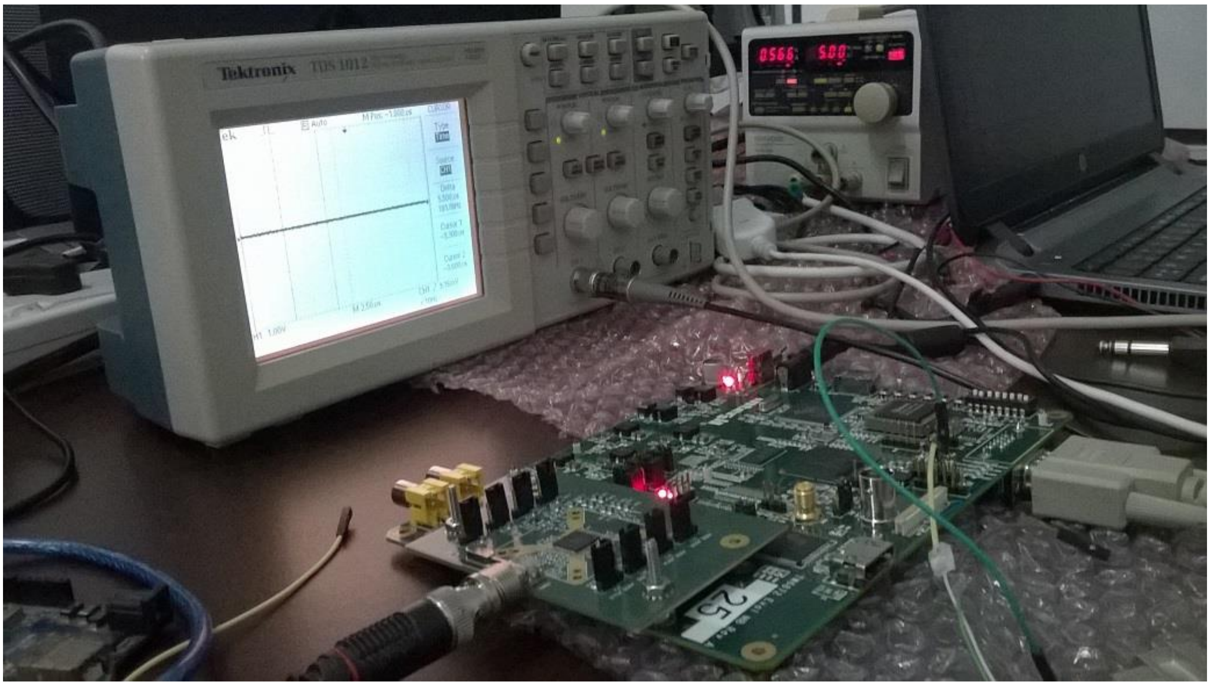

Figure 2.10: Testing TW6872 IC with the evaluation board

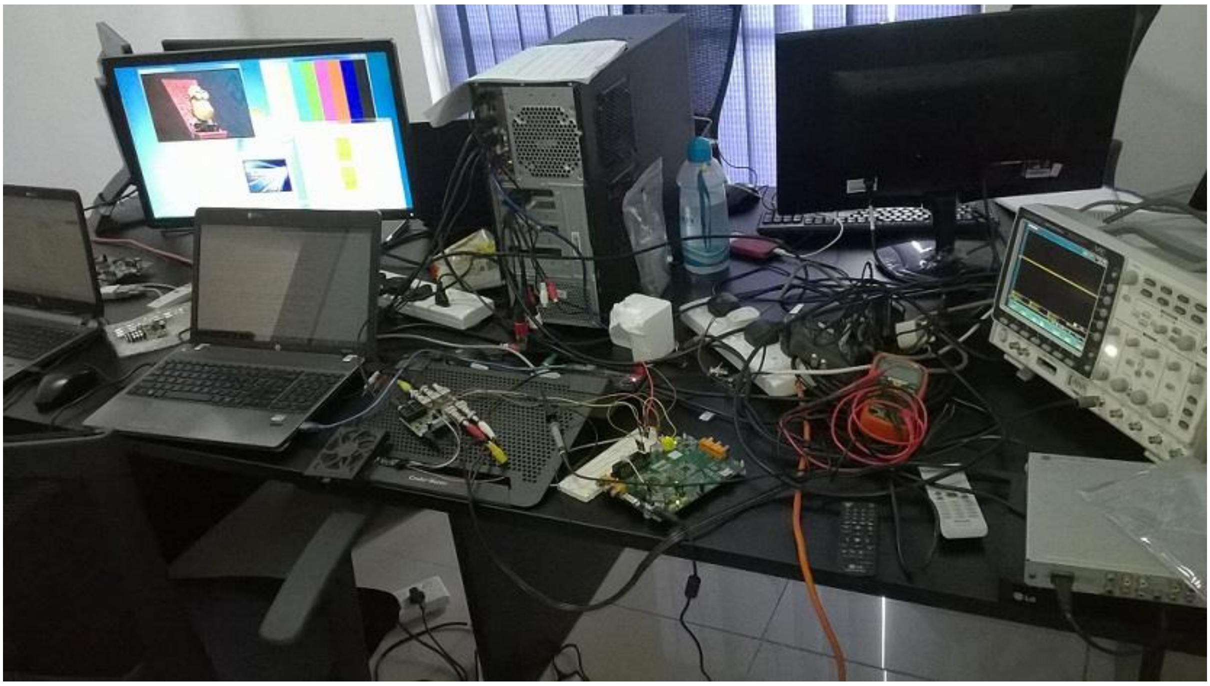

Figure 2.11: Work bench during testing process

Now we were able to get a video output through the BNC jack connected to the output side but the signal integrity was poor; the output video was flickering for all formats and high frequency 1080P video was not giving any output. Since the output was flickering but the internal pattern of the SDI transmitter IC was not flickering, it was concluded that the losing of integrity is in ADV7181C or in the link between the two IC's.

Further changing crucial parameters in ADV7181C we found that some parameters recommended for their evaluation board is not suitable for our circuit. Those register values are hardware specific. After changing those parameters specially after reducing the drive strength of ADV7181C the integrity was increased. It was concluded that the high drive strength given by the ADV7181C is causing power shortages for certain modules within the IC and shutting them off momentarily. Then we were able to get the output for all formats and gradually we were able to fine tune the circuit. This whole sequence of testing gave me a lot of knowledge about what should be done and how we should find faults when a brand new circuit is not functioning as expected.

There were several faults that could not be corrected by firmware or small hardware changes to the same prototype. All those were recorded and changed in the second prototype. One such fault was in the audio input circuit. In the first prototype only one audio channel worked because a foot print of an audio connector had been placed in wrong direction and therefore one active line had been connected to the ground. There were several such mistakes that were changed in the second prototype.

The audio processing was also done by the SDI transmitter IC TW6872 but it was noisy. So we suggested the client that we can increase the quality of the audio output by implementing a separate audio processing unit in the circuit but it requires some more components and increases the physical size and the cost of a unit of the device. They decided to stay with the current design for the first version and implement that in a later version of the device.

When the second prototype was received from the manufacturer we started the testing sequence back again from visual inspection and power level testing. Then we gave power and programmed the device and it gave a video output at the first try itself but some formats were flickering. Certain hardware specific parameters had to be fine-tuned for the new prototype to increase quality of the output video. And only a very few hardware changes were noted this time. One such change was the in values of a resister bank in the high speed link between the two IC's. Those resisters were changed to reduce the impedance of the connection.

Once all those were noted the third prototype was made and then the firmware was fine-tuned for the new circuit. The client has informed the company that they are going to produce 100 units of the device as the first batch and also to produce more on the success of the first batch.

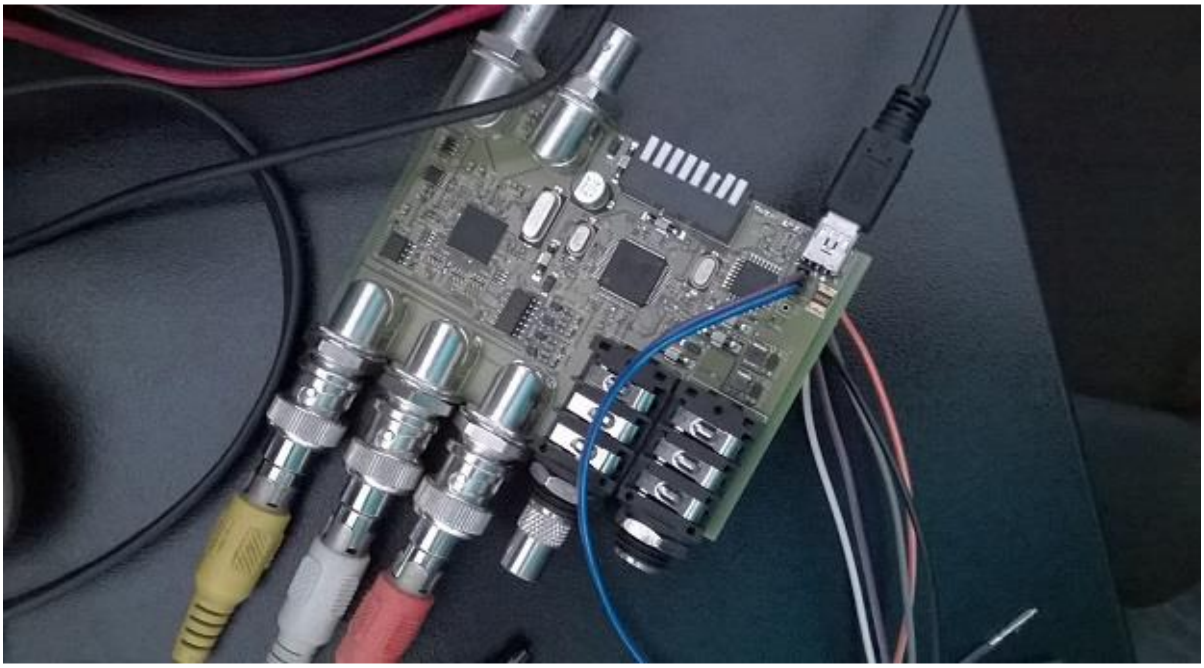

Figure 2.12: I2C lines are tapped in blue and purple

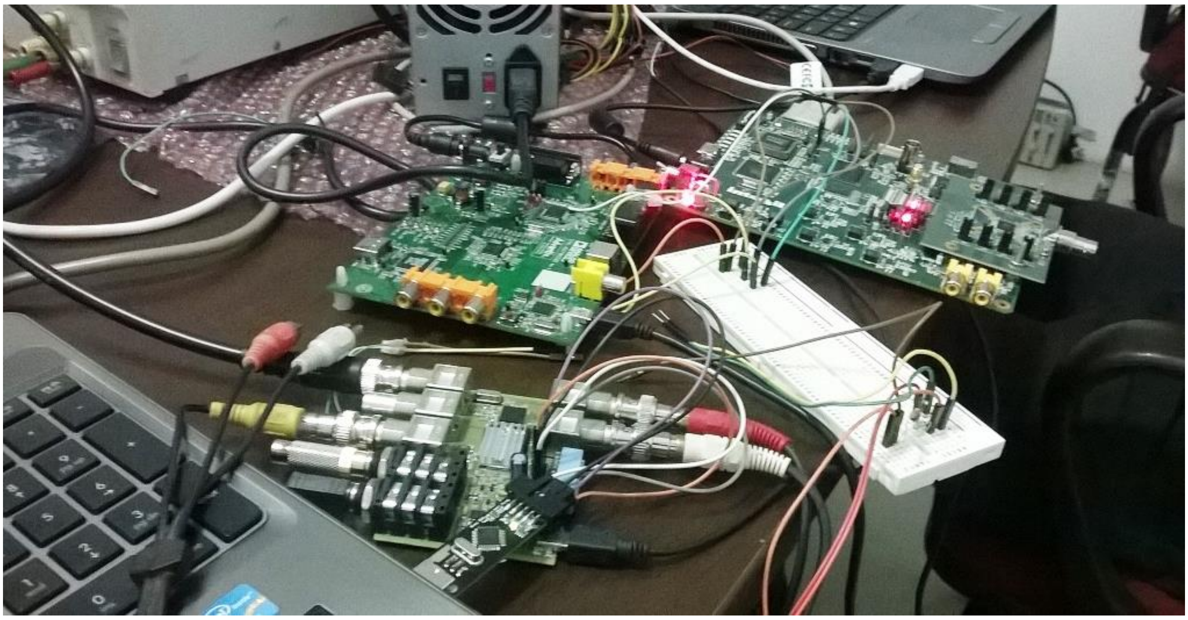

Figure 2.13: I2C lines of all three circuits joined

2.2.2. Analog to HDMI Video Format Converter.

2.2.2.1. Project Overview

Analog to HDMI converter is a project quite similar to the previous Analog to SDI converter project. This project is also for the Osprey Incorporation in USA and it’s a total spec to product development. The final product is expected to take analog video inputs of different formats and convert them to HDMI video. This project is still going on and I was involved in firmware development using the evaluation board. The hardware designing is still going on and the first prototype is expected to be ready by the end of April 2015.

Similar to the Analog to SDI converter project this device should also be able to get input in three types,

- Composite (CVBS) –via one BNC connector
- S- video (Y/C)-via two BNC connectors
- Component (YPbPr 4:2:2) -via three BNC connectors

In addition to the video formats supported by Analog to SDI converter, 525P and 625P are also expected to be supported by the Analog to HDMI converter.

All together the device should support PAL, NTSC as composite and S-video and following formats as component YPbPr 4:2:2 input,

- Component (YPbPr 4:2:2)
    - PAL – component
    - NTSC – component
    - 525P 60 Hz
    - 625P 50 Hz
    - 720P 50 Hz
    - 720P 60 Hz
    - 180I 50 Hz
    - 1080I 60 Hz
    - 1080P 30 Hz
    - 1080P 25 Hz
    - 1080P 24 Hz

The output of the device should be given through a standard HDMI port. For this design also, the customer emphasized that the device should work with USB power imposing a 500-mA current limit. Audio circuit should also be included to the design to convert analog audio to digital and embed with video.

2.2.2.2. Initial Planning and Hardware Design

Since the design group has experience in coping with ADV7181C analog to digital video converter IC, we decided to use the same IC for the analog front end. After much discussion about the HDMI transmitter IC we were left with two options; AD9889B and ADV7511. Among these two IC's ADV7511 is a newer one with more options and it is easier to configure. But we do not have any evaluation boards containing that IC. But we have an AD9889B IC in an evaluation board which we used for the previous project. Therefore we decided to use AD9889B as the HDMI transmitter IC. Since both ADV7181C and AD9889B are in the same evaluation board, we can test most of the features before manufacturing any prototypes. The other advantage is that we have the schematic and layout of the evaluation board and therefore we can reduce the time spent on developing the schematics and layouts. Atmega 328 was selected as the controller for this project also.

Keeping the design similar to that in the evaluation board we decided to use 8 bit and 12 bit versions of video so that the connection between the two IC's should have 12 data lines similar to that of the evaluation board. Therefore all the firmware development is also done with 8 bit and 12 bit versions. But the hardware design is yet to be built.

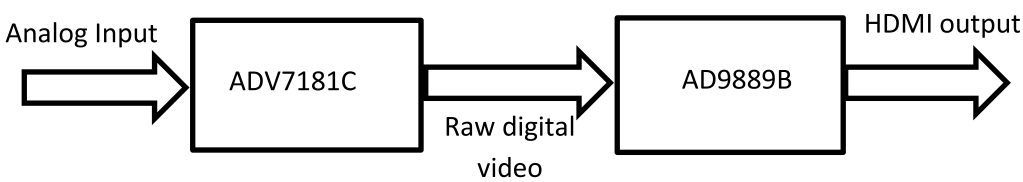

Figure 2.14: Big picture of the Analog to HDMI Video Converter

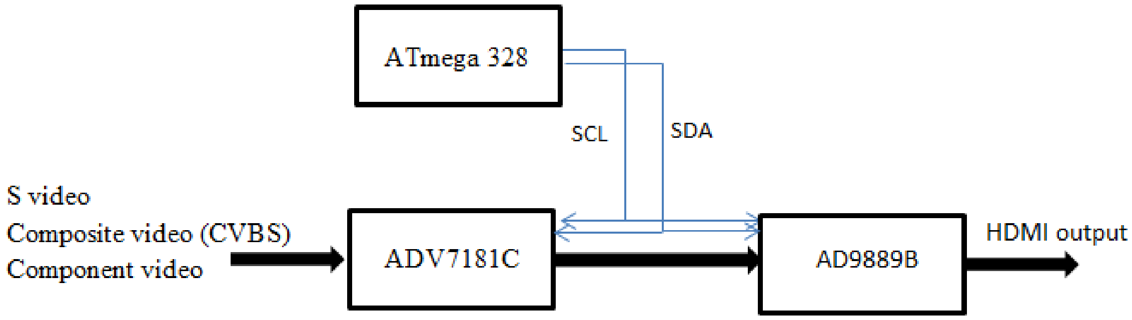

Figure 2.15: Analog to HDMI Converter Block Diagram

2.2.2.3. Firmware Development

Firmware development for this project seemed much easier than for the precious project because of the experience gained through the previous project and the familiarity with the design support files and datasheet of ADV7181C. On the other hand the fact that both IC's are available on the same evaluation board helped a lot. But the limitation was that the evaluation board does not support audio and therefore audio processing can be tested only when the hardware is done.

But taking the first video output was still a challenge and took few days. Adjusting the given sample scripts for formats that are not given was done using the ADV register control software given with the evaluation board. After getting the output it was fine tuned to increase the quality of the video. There was a problem of interlaced appearance in some formats and that was corrected adjusting the registers.

After all the scripts were prepared for all the formats that were available as video sources in the company, I prepared the scripts for video formats that were not available in the company such as 1080P 30 Hz. The parameters were kept similar to those of the closest available format. Finally I demonstrated the Analog to HDMI conversion in evaluation board using the prepared scripts and it worked fine for all the available video formats.

Then I started to write the C code using those scripts and the same structure was used for the code as in the analog to SDI converter. Auto detection was also implemented but they are yet to be tested because the first prototype has not yet been manufactured. I have documented all the progress of the project and handed over them with the codes so that anybody can proceed from there without much trouble.

2.2.3. HDMI Transmitter Module for ZedBoard Project (FPGA project)

2.2.3.1. Project Overview

I spent last six to seven weeks developing a HDMI transmitter module for ZedBoard to facilitate HDMI output from the FPGA. Although it required a lot of knowledge about digital high speed signals, standards for digital video, and sync pulses and synchronization, I had already acquired an enough amount of knowledge and familiarity on those topics from the previous two projects. Therefore the only new sector was the FPGA programming with Verilog. I received quite a lot of instructions on developing Verilog designs using Xilinx vivado development environment from my immediate supervisor Mr. Kalana de Silva. The two workshops given in the early days of the training program became a big advantage in this regard.

Zed board has a HDMI transmitter IC but it accepts input data only in a set of given formats. It should also be provided with video clock and synchronization pulses and it should be configured in the correct format to give a HDMI video output.

The task of this project is to develop an interface between this transmitter IC and the FPGA to get the video data from the FPGA and give it to the ADV7511 IC in the required format. The module has to configure the HDMI transmitter IC to the relevant format and also generate required precise sync pulses for synchronization of the video. It should also buffer input data in order to keep the integrity of the video.

2.2.3.2. Initial Planning

Initial plan of the project is to take input data in a specific format and configure the IC using I2C communication. The I2C modules can be taken from a previous project completed in the company (reuse). Sync pulses should be generated by the module taking input clock from a Xilinx core. Since this is not a standalone product but a re-usable part of a product, the module should be parameterized to enable adapting to different video formats according to the application. The modules should be re-usable and easily adaptable to application.

Initial high level block design was developed with a module to generate the sync pulses for synchronization using an input clock from a Xilinx clock generator core, a pattern generator module to generate an internal pattern, a fifo buffer core to buffer the input video data. Two switches can be used as one for resetting the module and the other for selecting between the input pattern and the input video data.

The FPGA and the ADV7511 have only 16 data line connections and the IC requires a colour depth of 8 bits which means it cannot be given RGB data other than YCbCr data. Therefore input video should be given in YCbCr 4:2:2 format with 8 bit colour depth.

In the initial version the module configures the ADV7511 into input format 1 described in the datasheet which is 1080P video with refresh rate (fps) 30. This is format 34 in CEA-861-D, standards for uncompressed high speed digital data. Synchronization pulse requirements of this format are shown in the Annex 1 of this report. This format can be changed by changing the configuration settings and relevant local parameters in the module.

2.2.3.3. Methodology Followed

After analyzing the requirements and specifications, a higher level block diagram was drawn. After holding long discussions with the immediate supervisor, a detailed block diagram was drawn. This detailed block diagram was used as the guideline in developing the modules.

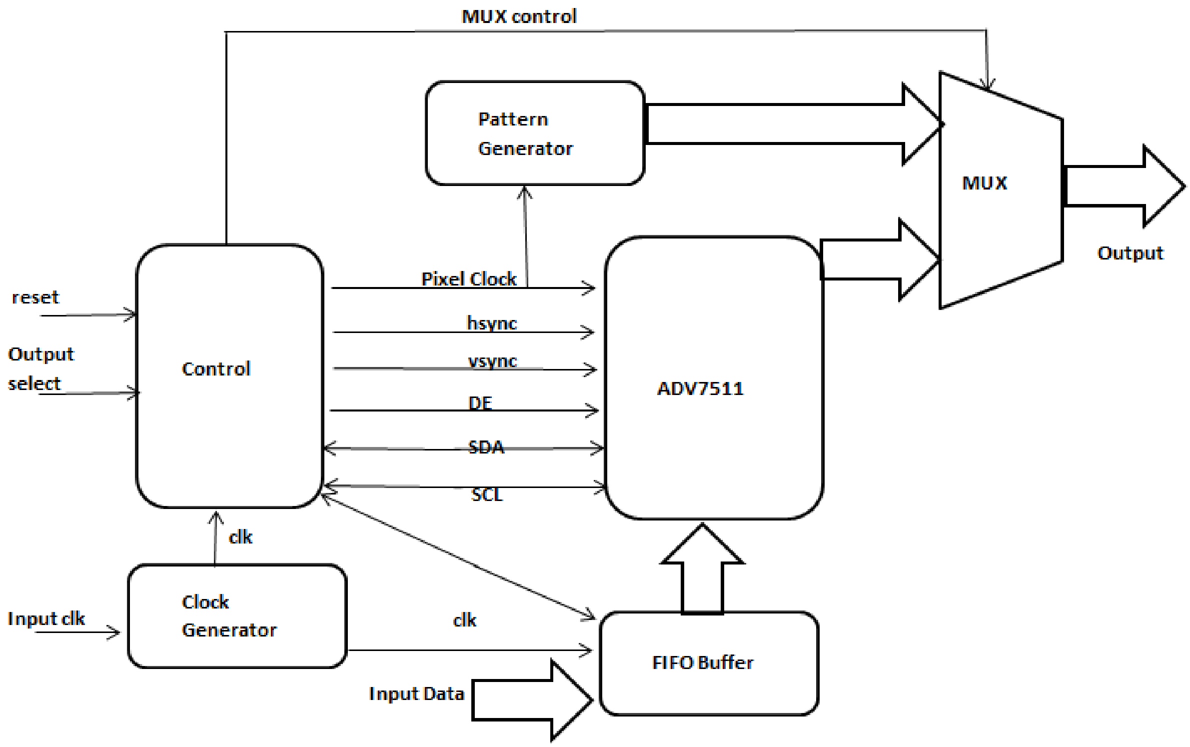

Figure 2.16: Block Diagram of the System

Verilog codes were written for pattern generator module and control module and a Xilinx core was integrated for the input clock. Module “Control.v” takes the input clock from a clock generator core and generates pixel clock, hsync (horizontal synchronization pulse), vsync (vertical synchronization pulse) and DE (Data Enable signal). It also controls the fifo taking inputs from fifo such as fifo_full and fifo_empty.

The control module also contains sub modules for I2C read and write operations which were taken from a previous done at the company by Associate System Architect Mr. Kalana De Silva. Those I2C sub modules take care of the hardware level I2C signal transmission. I incorporated those modules to the control module of my design.

Taking input from the user via two switches assigned is also done by the control module and it uses that input to reset the other modules when required and to select between the input video and the internal pattern. The sync pulses generated by this module are customized to the selected video format by the set of local parameters set in the module. The user can change the video format of the output by changing those local parameters and the register settings that are transmitted to the IC using the I2C modules. Those register values are also included in the same module (control module).

The pattern_generator module is responsible for generating an internal pattern to be sent out as the video output when the user selects input pattern. It takes the pixel clock as an input and gives data synchronized to the pixel clock. Fifo buffer is a Xilinx core used to buffer the input video data. It has the capacity to store 1024 bytes of data in it. It gives feedback such as the fifo_full, fifo_empty to the control module.

Verilog modules written in the first part of the project were simulated and tested using vivado environment. Through that I gathered experience on writing effective test benches and simulating them to find errors. The sync pulses generating module was simulated numerous times and adjusted to get the precise sync pulses with exactly the same number of pulses in a stipulated time interval according to the CAE-861-D Standards for uncompressed high speed digital data.

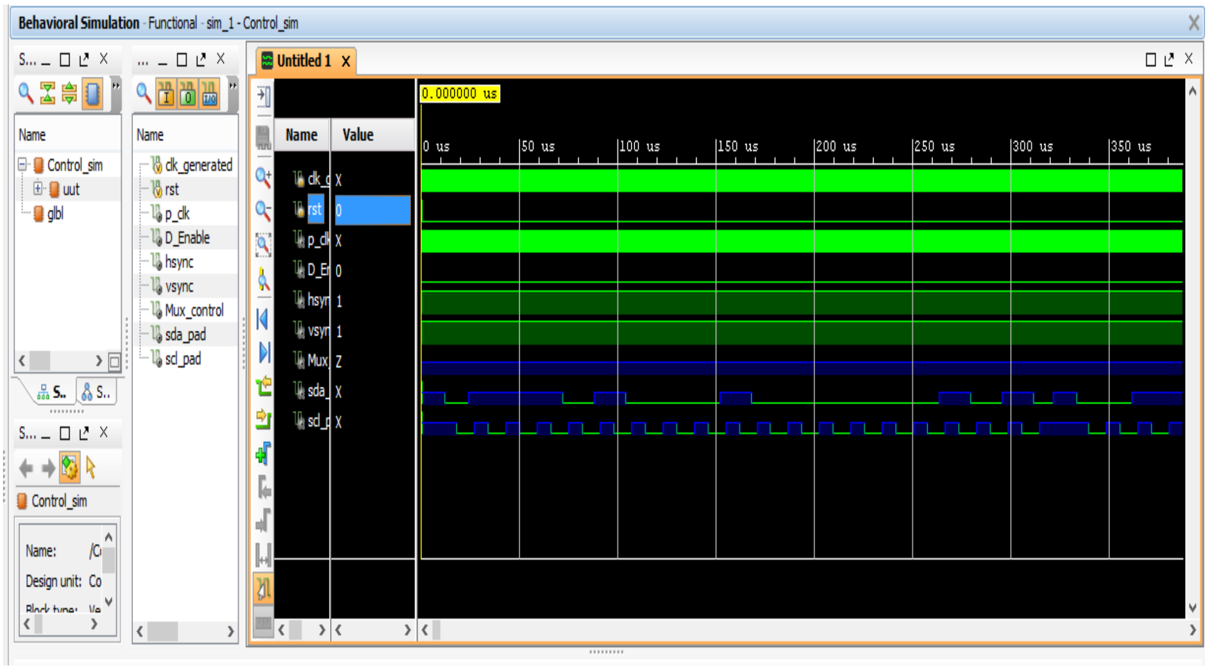

Figure 2.17: A simulation of the Control.v module

Initially the simulation of the control module was done without the I2C sub modules because those modules require feedback from the other end of the I2C communication to proceed in the state machine. After generation of precise hsync, vsync and DE pulses I2C sub modules were activated making required changes in the state machine.

But with the addition of new features such as the I2C modules, the design was difficult to be simulated by test benches because most of the modules require responses from the other side. For example, the I2C modules require the responses in terms of acknowledgements at the right time from the opposite side. Writing test benches for such modules is difficult and very time consuming. Therefore I implemented a debug core to test the design using “SetUp Debug” in vivado. This was the first time I implemented a debug core and I received instructions on how to implement a debug core and set ILA (Integrated Logic analyzer) probes in Verilog ChipScope to debug the module.

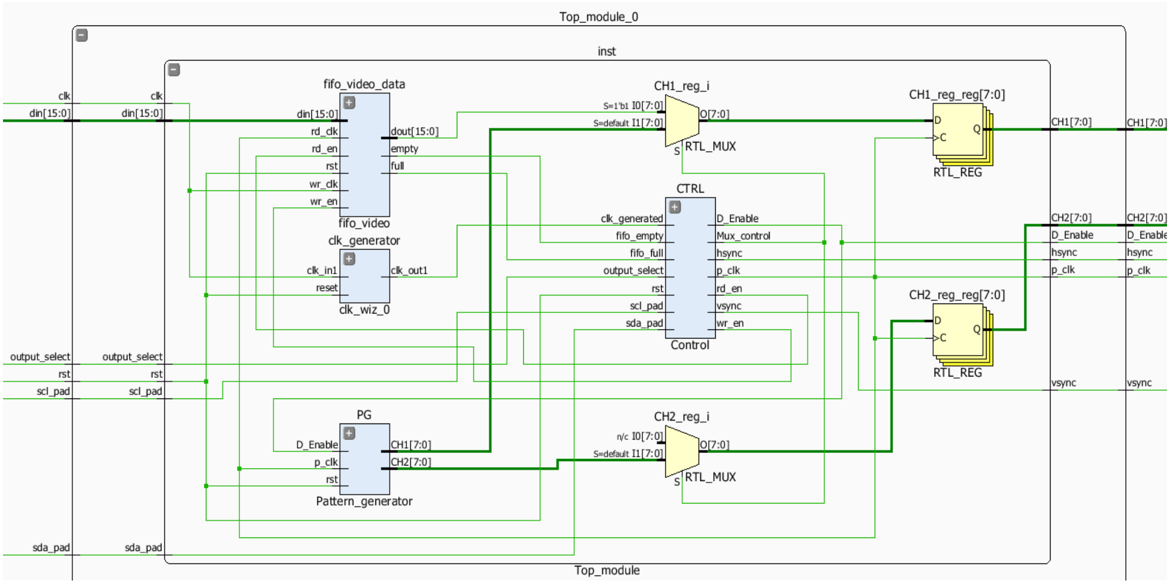

Figure 2.18: Elaborated Design of the system

The project requires a constraints file (.XDC file in vivado) to assign input and output pins from the zed board. Therefore I wrote a constraints file to assign them as required using the master constraints file provided by the zedboard.org website and the user guide of the zed board. In re-using this project, the same constraints file can be used if the new design is also for a zed board. But if it’s for a different board with the same HDMI transmitter IC, the constraints file will have to be changed.

I faced a problem with getting logically wrong output from the project when the debug core was implemented. After scrutinizing the synthesis design it was seen that some logic components are being removed from the design. When inquired from the instructor, I got to know that it is a bug with the vivado platform to remove useful logic at times in an attempt to optimize the design in synthesis. So I had to write a constraint file (usually called “dont_touch” constraints file) to avoid optimization in the synthesis process.

When more nets were added for debugging, the debug core stopped working. When asked from the instructor he said that there is such an issue with the zed board and asked to package the project as an IP core and import it from a separate vivado project and connect a zynq processor to that project to get the input clock. If it wasn’t for this issue of the zed board, the design should be able to run with the input clock from the FPGA. But due to this issue, the design has to take an input clock from another processor. But merely getting the zynq processor doesn't give the input clock. It has to be kept running to get the input clock. Therefore hardware specifications were exported to vivado SDK (Software Development Kit) and a 'hello world' program was put to the zynq processor to keep it running. Once that was done, the debug nets were selected and a debug core was created in the new vivado project and it worked without any issue.

By solving that issue I learnt to package a RTL project, import a created IP core (packaged project) to a project, export hardware to a SDK and write a program to a processor using the SDK and program it.

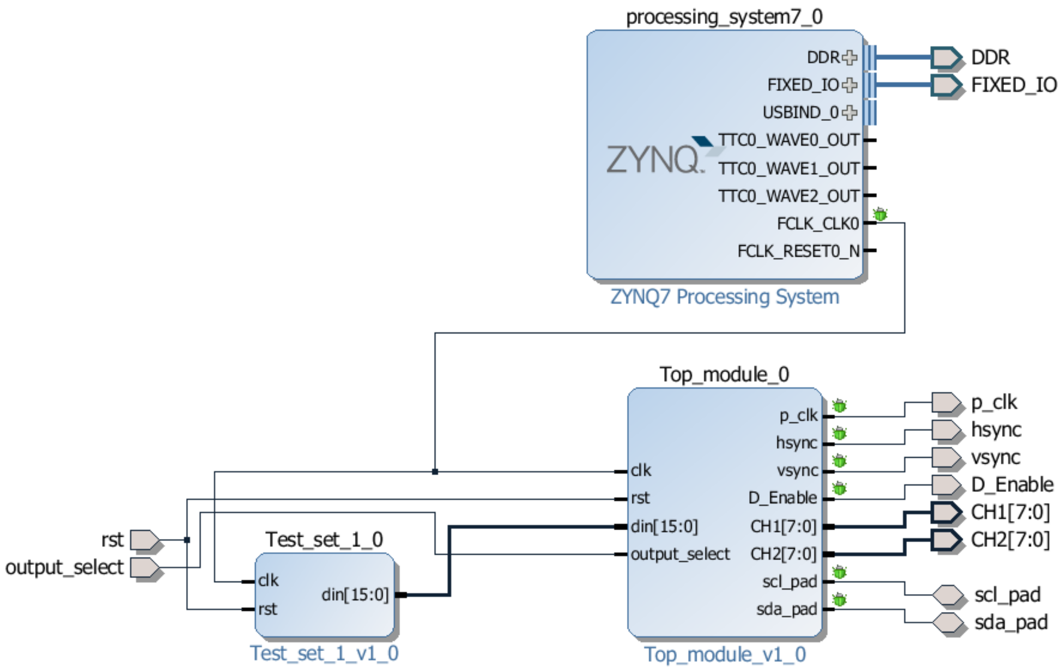

Figure 2.19: Block design after packaging the project and adding a zynq processor

Integrated a fifo buffer with a depth of 1024 data bytes using a Xilinx fifo generator core to the design to get the input video data from the processor and give them to the transmitter IC. Then a MUX was added to select between the internal pattern and the input video data according to the user's choice taken through a switch. Another switch was assigned to reset all the modules when required.

Another small project was created to give input video data to the above project as test data and that project was packaged under the name "Test_set_1_0". That packaged IP was also imported to the project as a separate core and used it to give input video data to the project.

Then the bit stream was generated and programmed to the zed board and the output was observed using a projector.

Then the design was up to a level that meets the requirements; It successfully configures the ADV7511 HDMI transmitter IC, generates the sync pulses and gives internal pattern and input video data as output according to the user’s choice.

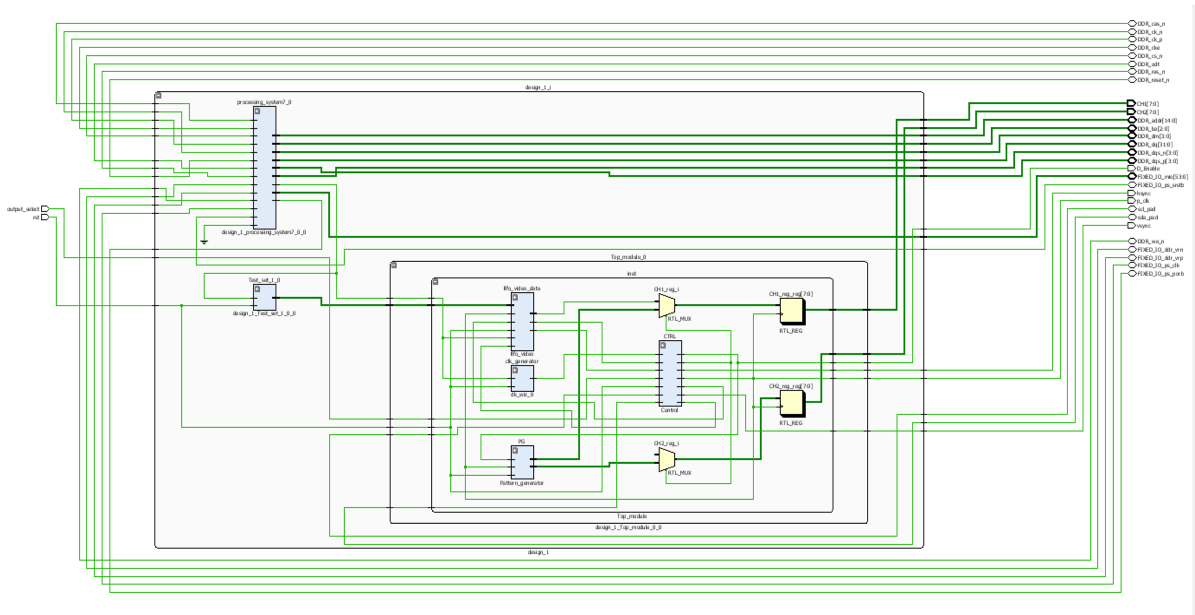

Figure 2.20: Elaborated Design after adding the Zynq processor

Then the next task was to make it easily adaptable to different video formats. The initial design was configuring the IC to 1080P at 30-fps (frames per second) and it required some values to be changed in settings transferred via I2C, input clock and some parameters in sync pulse generation to be changed to adapt it to a different video format. In order to make it easily adaptable to different formats I parameterized these values and mentioned them in the documentation so that anybody can use the module easily in their future projects changing those parameters according to the application.

In addition to that we were instructed at the beginning of the RTL project to follow a certain set of coding guidelines that are followed by all the engineers in the company. Templates of Verilog codes written according to these guidelines were also provided with instructions. These coding guidelines make the codes easily readable and understandable to all the engineers in the company without much effort so that they can be reused in future projects. I benefited from this because I was able to use the codes for the I2C modules from a previous project done at the company. Getting used to these guidelines will be an advantage even in my future projects also. Having the codes adhered to these guidelines allows the extending of one's work by another from where the first person had left off.

Likewise I learnt a lot about both implementation and simulation flows in digital design and got hands on experience in developing a system using vivado development environment.

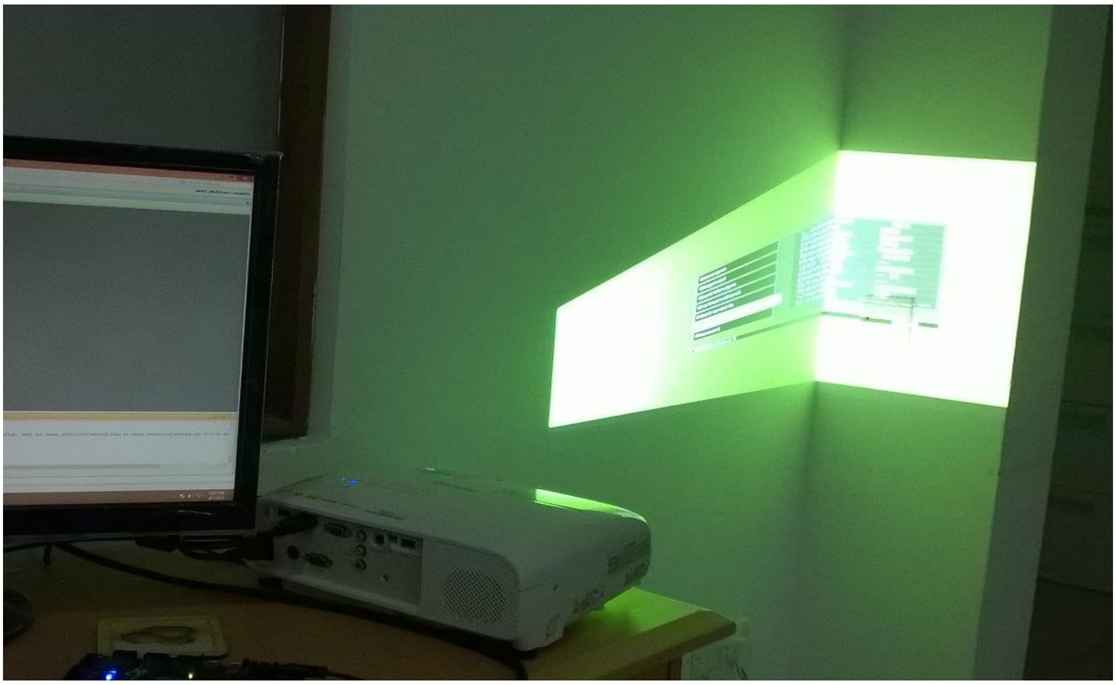

Figure 2.21: Test Video Data given as output via projector

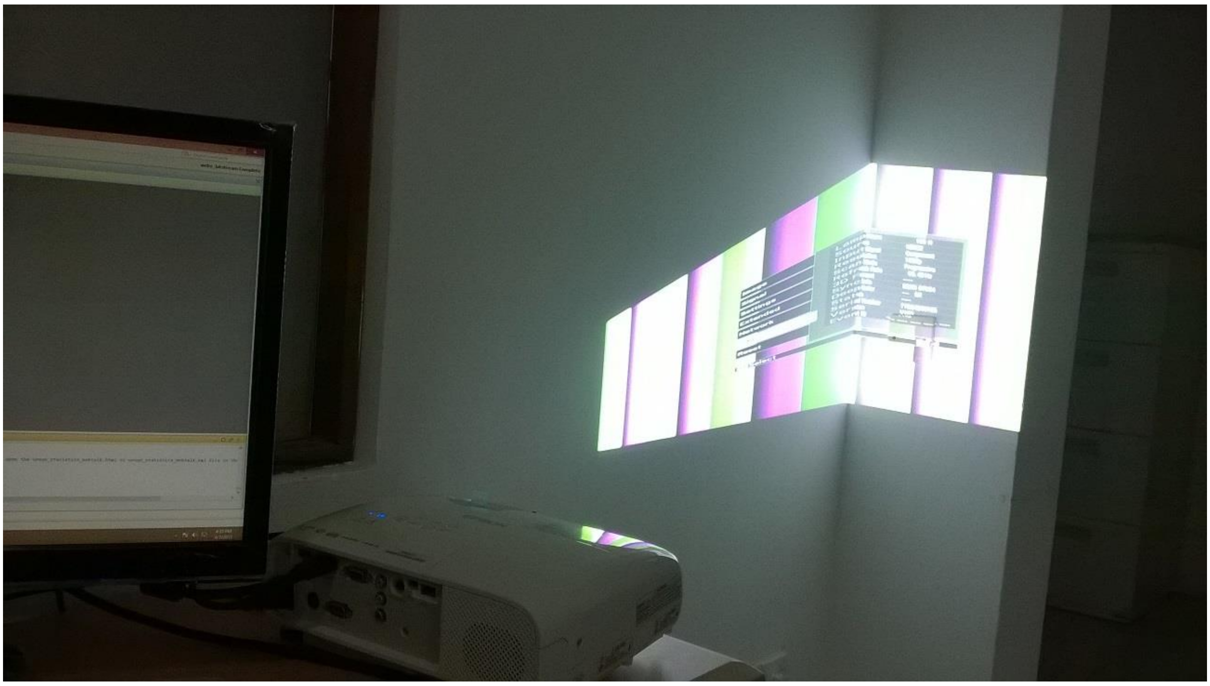

Figure 2.22: Internal Pattern given as output via projector

2.3. Exposure and Work Environment

ParaQum Technologies is a fast expanding startup with a set of highly talented young engineers. Startup background brought a lot of opportunities for us as interns. Each project group comprised of a very few people so that almost all get the chance to directly communicate with clients. In my case, both embedded systems projects were done for the same company, Osprey Incorporation which is an electronic product manufacturer specialized in broadcasting industry. It operates in four countries; USA, China, Switzerland and Sri Lanka. Their operations in Sri Lanka are functioning via Vario Systems in Negambo.

In those two projects I was joined to the email thread between Osprey and ParaQum to get clarifications on their requirements. In addition to that I got the opportunity to meet Mr. Rogger, a managing director of Osprey and an electronic engineer from Osprey USA when they visited ParaQum last January to see the progress of projects they had offered. I got the rare opportunity to work with those two in debugging our first prototype in the two days they were in ParaQum.

When the prototypes were delivered by the foreign manufacturers we started testing and found some hardware faults which can be fixed in the same prototype rather than going for a new prototype. But the highly compacted nature of the device made it almost impossible to do them manually. Therefore we were given the chance to get them changed by using technically advanced assembly lines in Vario systems. So we went there and got them fixed using those machinery. There we got the chance to meet the managing director and several other high ranking officials at Vario Systems and show them our product. These visits were a kind of field visits for me because I learnt a lot from observing technically advanced manufacturing lines and machinery. Discussing and working with experienced technicians gave me a fair amount of knowledge.

The FPGA project I was involved in was for the internal use of the company. They intend to use it for FPGA projects that they do using the zed board. Therefore it didn't have an outside client to deal with. But designing it to make it reusable as much as possible made it more challenging. The design required to be easily adaptable to different video formats. And the code should be readable and easily understandable for others. Therefore I had to follow all the coding guidelines and good practices according to standards set by the design team at the company.

With regard to the work environment, it was a team working place. The project group work together as to bring up the final product with the best possible quality in the shortest possible time. Both engineers and interns were considered the same in a project group although the interns always got instructions and guidance from senior engineers. I think the narrow age gap helped this. We were assigned tasks and made to take responsibilities in certain occasions forgetting that we were interns. Lack of Responsibility is the factor that makes work easy for interns. But interns should get used to working as engineers by holding some responsibility. I was lucky get both those exactly in required amounts.

2.4. Problems Encountered and Solutions

Working on three projects especially in industry level for the first time, I encountered a lot of problems. Most of them were technical and specific to the project while few were encountered in all the projects.

The first challenge in all the projects was to understand the requirements of the client. If we don't understand them correctly, they'll never be satisfied with our product. On the other hand it's not a good practice to trouble them asking for clarifications all the time. Therefore we should be free minded and we should have read on that specific topic and have a good understanding on the topic.

Once the requirements are clear we have another challenge in background research. It should be properly done to foresee the issues that we are likely to face in design process. A situation we faced in analog to SDI converter project can be cited as an example. Initial requirements document had 625p and 525p video formats in the list of input formats and we didn't notice anything special with it. But later in design process we figured out that those two formats cannot be added because there wasn't any SDI transmitter IC in the given price range capable of handling them. Therefore we had to inform it to Osprey later in our design process. Although it didn't cause any damage it should have been found out in the background research.

Another issue faced was the lack of experience in the video processing field. These two were my first projects in that field so I had to read a lot and do a lot of research. If I had more experience it would have been easier especially in understanding datasheets of video processing IC's. Somehow I gathered an enormous amount of knowledge and experience on that field through these projects.

The other most frustrating problem encountered is the fact that design support files of most of the rarely used IC's have errors. I found many such errors with the "software users' guide" of ADV7181C. It had wrong register values assigned in several tables. These errors were found only after lot of testing. Therefore they cost a lot of time and effort. Similar kinds of errors were found in sample scripts given with its evaluation board. TW6872 IC also had such issues in sample code given with its evaluation board. Since these IC's are used only by developers there are faults that haven't been discovered. This makes the debugging extremely difficult. But as a developer that has to be tolerated.

Most of the problems with regard to these IC's when searched online do not generate enough results. This also became a challenge in all projects. The fact that they are used only by a limited number of developers is the inevitable cause for this also. Support forum of Analog Devices namely "Engineers' zone" gives some sort of a solution for this. Support staff of Analog Devices as well as developers from around the world help solving each other's issues through this forum. Therefore it is very important to make an account in that forum and use it if someone is using an IC by Analog Devices in a project. In addition to such support forums, I directly contacted support staff of certain device manufacturers for solving some issues. Through that I recognized that some of those issues have been found for the first time or that could be the first time that IC is being used for that particular purpose or application. This was a help for device manufacturers also to correct faults in their design support files.

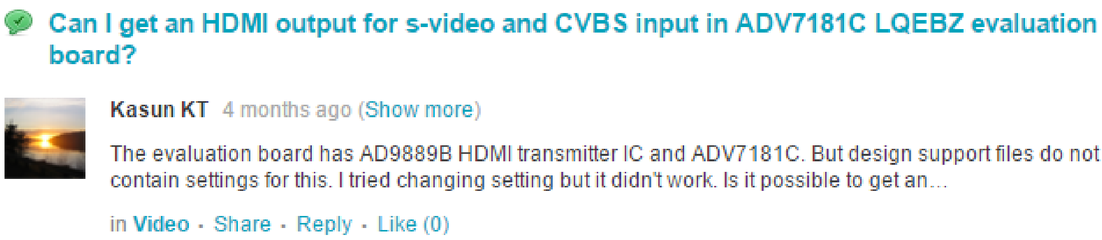

Figure 2.23: A question posted in Analog Devices Support Forum about the Evaluation Board

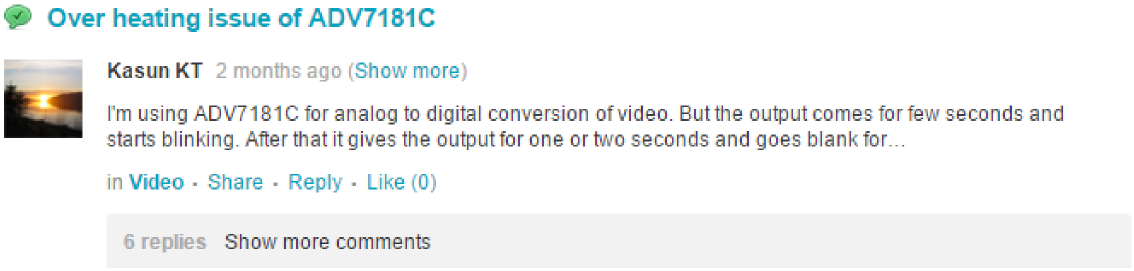

Figure 2.24: A question posted in Analog Devices Support Forum

Another challenge faced in FPGA projects was the large amount of time taken for synthesis and implementation of the vivado project. The computer has to be a very powerful one to do the processing quickly. Even then it takes a lot of time so that the developer has to wait a lot of time after each correction of the code. Therefore the developer has to do several corrections at the same time before synthesizing or implementing and also manage time intelligently engaging in some other activity while the project is being implemented or synthesized.

Unavailability of certain resources for some projects was a barrier for the projects. The company tried its best to provide all the resources required as much as possible but being a startup there were some short comings. For example, the unavailability of an eye diagram analyzer to analyze the quality of SDI output was a problem in that project. Such an analyzer is not available in any of the institutions in the country so that ParaQum couldn't burrow it either. So the device had to be sent to the client without testing using an eye diagram analyzer. High frequency oscilloscope with a sampling frequency of over 1-GHz was also a resource that wasn't locally found in any of the institutions.

Another such example was the inability to find video sources of several formats. The company bought a Blu-ray player as a solution to this but it also lacked outputs of several formats as component video output (eg: 1080P 30 fps). As a solution to this we were able to develop a 1080P component video output using an evaluation board. We used an evaluation board containing ADV7341 IC as a video encoder and programmed it to a 1080P format and gave the necessary pixel clock using another IC in the same evaluation board. Then we programmed the encoder IC to generate its black and white internal pattern and the expected output as component video. This was used to test the device for 1080P formats at refresh rates of 30, 25 and 24 but this took a lot of time and it was only black and white so that we could not test the colour quality of those formats.

Lack of familiarity with the development tools is also a barrier to a new entrant. For example, the fact that the zed board stops working with debug cores when a large number of debug nets were added should have been known by the developer to proceed from there on. Likewise there are many limitations for a person who does not have enough familiarity with the boards and development tools. This training program was a big opportunity in that sense to gather information and get familiar with them.

2.5. Hands on Experience and Skills Acquired

Both embedded systems projects were on developing video processing devices. Therefore first few weeks were totally spent on reading about analog and digital video formats and their specifications including CEA standards for uncompressed high speed digital data and BT.656 standards. Through these I was able to gather a huge amount of knowledge in video formats, specifications and processing. This was evident from the fact that I was able to finish the initial work of the HDMI transmitter module project (FPGA project) which required a considerable amount of knowledge on video formats and standards in a very short time.

Then we received evaluation boards for testing several IC’s. After that the hardware and firmware development processes were initiated. The whole process was a great experience and brought me a lot of knowledge and experience. I was entrusted with the task of developing the firmware to run on the brand new device. Coding for a brand new system with such complexity was a great opportunity for me to challenge myself to expand limits. It also gave me confidence to proceed in firmware development for larger projects. Similar kind of process was followed for the second embedded systems project also. But I was able to complete my task easily with the experience gathered from the previous project.

I got the experience of working with complex evaluation boards used to test complex integrated circuits and finding suitable ways of application. Hands on experience were gained to use high frequency oscilloscopes, spectroscopes, logic analyzers, etc. in testing, debugging and fine-tuning circuits.

Debugging these devices once the initial prototypes were received from manufacturer was a huge challenge for the whole team. Once the device didn’t work we had no clue at all on which part is not working. It could have been either hardware or firmware or both. There we followed a lengthy sequence of testing to find the faults and fix them. Several minor faults were fixed there itself while certain others were spotted to be fixed in the second prototype. This lengthy debugging process went for about a month and gave me the opportunity to get hands on experience because I was one of the only three people involved in the process. The debugging process was the best experience I gained in the training because it taught me the way of bringing a circuit that doesn't give any output at all to a level that gives the expected output with high quality. The procedures, practices and steps followed in the debugging all have their reasons to be followed in that sequence. For example, testing the output side before the input side gives a better chance of finding the bug because of the output side has the bug it must not give the expected output from the output side.

I also gathered a lot of knowledge on I2C communication, its strengths and limitations as well as methods of exploiting those limitations and strengths for our benefit in designing and testing circuits.

Through the FPGA project I was able to gather knowledge and hands on experience in both implementation and simulation flows of digital design. And I got the chance to test and debug the system using debug cores, ChipScope and integrated logic analyzer probes. Packaging and importing projects as IP cores were also done while Xilinx IP cores were also integrated to the design. The project developed for zed board gave me a lot of familiarity with the board as well as the HDMI transmitter which is used in other boards of that series of boards. Working with vivado development environment gave me the much required experience to build larger projects with that environment.

Getting used to working with "asana" project management tool will be a big advantage for my future projects because it allows effective management of projects when a group of people are working on the same project. With asana, all the team members are updated with the current situation of the project and what each of them are required to be doing in the next few days to keep the project moving on track. This tool also provides calendar synchronization and various other features that helps a person to manage his own work while staying in pace with the progress of the project group.

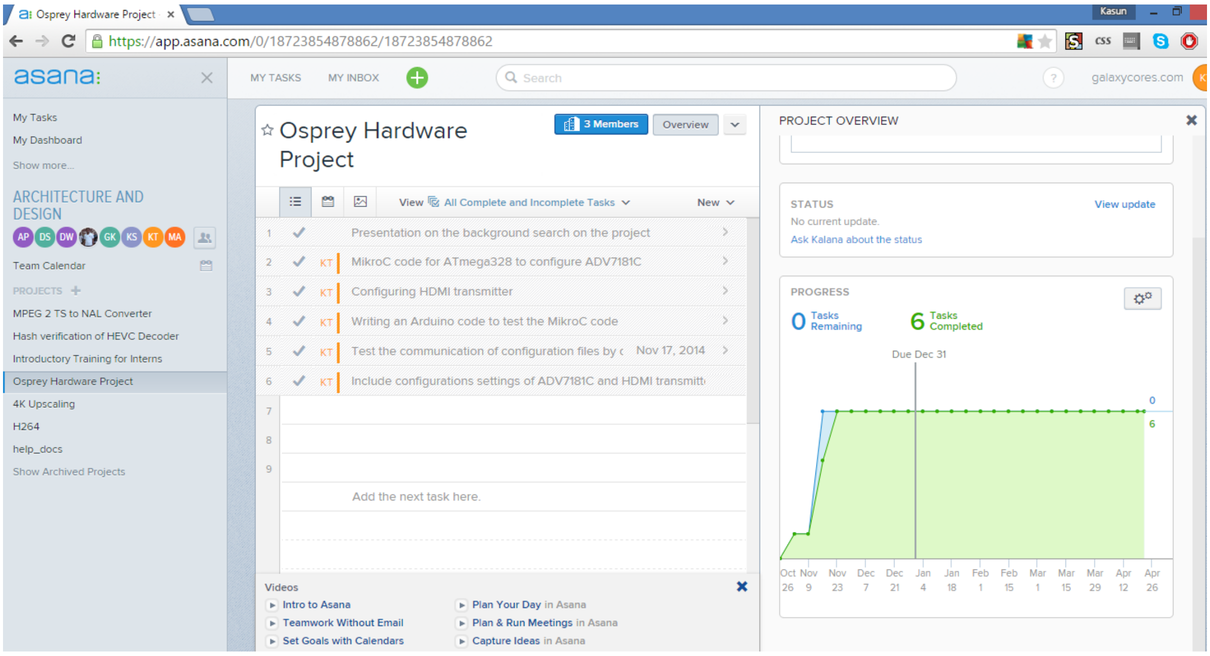

Figure 2.25: Project Management with asana tool

Storing all the codes in GitHub using the Source Tree open source software was another important experience I gained because most of the software and FPGA projects have lot coding. In university projects, we encountered many situations where we lost our progress of the code by trying to add new features to the existing code. Even in some robotics projects we found ourselves in terrible positions losing the working code due to a new feature added to the code in the last moment. This repository system gives an ideal solution for this issue storing all the codes and its progress sequentially.

It gives chance to roll back to a previous instance of the code at any time and also keeps track of deviations we make adding new features as branches in the progress of the code. Therefore having experience in using this will help me in my future projects.

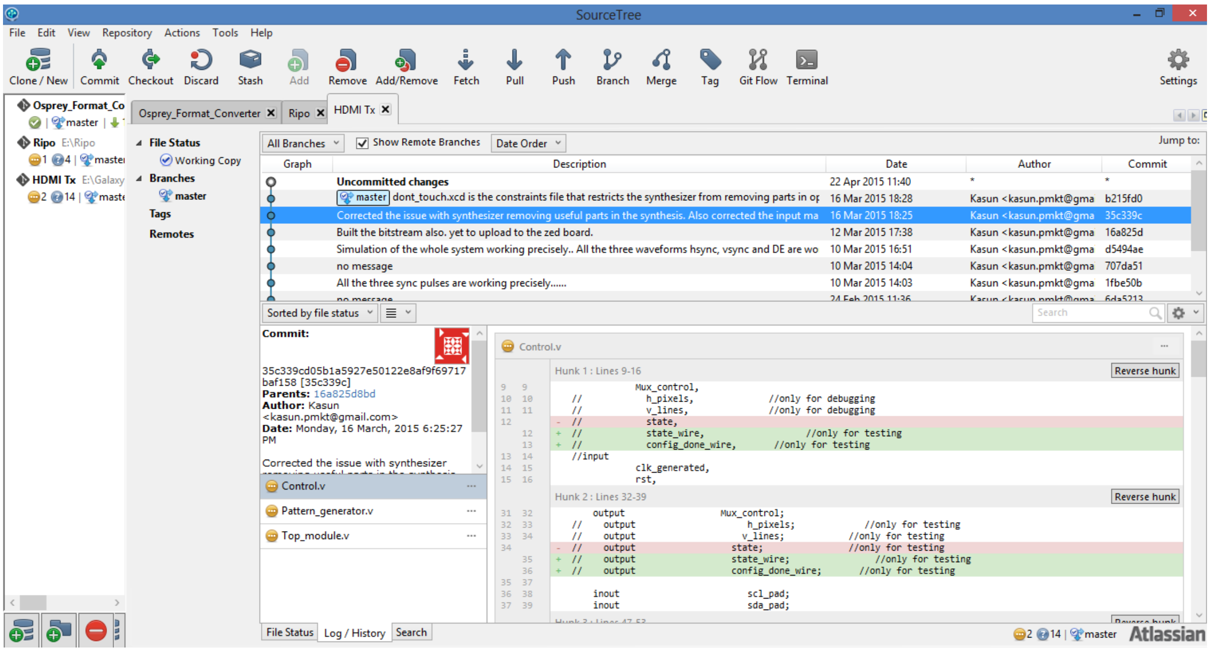

Figure 2.26: Using Source Tree to manage the Repository

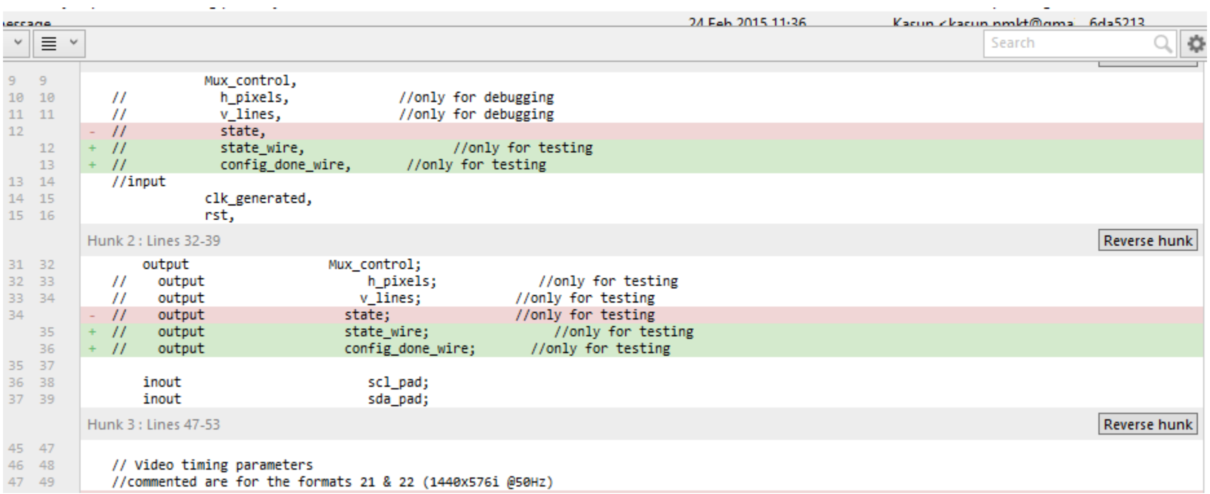

Figure 2.27: Managing repository: Removed lines are marked in red and new lines are in green.

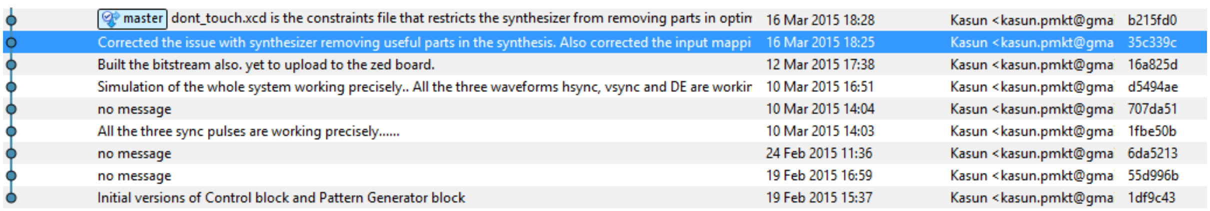

Figure 2.28: List of the code changes in the repository

3. CONCLUSION

3.1. Conclusion on Training Experience

The training experience at ParaQum Technologies (Pvt) Ltd can be considered as a period of fast learning and skills improvement for me. I got to learn a lot of new things in a short time which I couldn’t have learnt by reading or listening. I was able to acquire a lot of knowledge on how a project is being carried out right from the beginning from negotiating with the clients to the final delivery and providing updates. I myself witnessed and took part in most of the steps in that process. It was actually a privilege to be a part of three projects out of which two were directly for an external client. The training showed me how the industry operates, how projects are carried out, how products are manufactured and what kind of a role I can play in it.

It also gave me the chance to learn about my own skills, capabilities, strengths as well as weaknesses and gave me opportunities to correct those weaknesses. Working with a highly talented group of engineers was another great opportunity for me to raise my knowledge levels as well as attitudes. Friendly environment in the work place with a really good bunch of friendly people was extremely conducive for dedicated working. It provokes innovative ideas and brings best out of the person.

In addition to the technological and academic knowledge I got the chance to gather a lot of information and experience on co-operate environment in the industry and the ways to enjoy it. I believe this will help me to adapt to a workplace very easily.

The force that drove me through the training period was the genuine willingness to take on challenges and experiment new things and that was the main reason behind working for 25 weeks although the stipulated time period for training was only 21 weeks. This also proves the fact the training experience at ParaQum was exceptional.

3.2. Shortcomings and Areas to Improve in Final year at University

Although all of my projects required a considerable amount of knowledge on video formats and specifications, I had very little knowledge on that field when I started training. Therefore I had to read a lot and work hard to gather information to start the projects. I see this as an eye opener to read more and more about all the fields related to electronics engineering. An electronics engineers should have at least an overview on all the electronic related fields. Therefore I hope to read more on those fields and improve my knowledge in it.

Another shortcoming I identified is the lack of experience in analog circuit designing. As a solution to this I'm trying to learn circuit designing software and do some hobby designs in my leisure time.

Within the training period I felt as if I found the real meanings of some of the theoretical facts learnt in the university. Those made me understand those theories better. Therefore in the next year at University I hope to search a bit more about the applications of theories I learn in lectures so that I will be able to understand them better.

3.3. Conclusion about Projects and Training Establishment

The analog to SDI video converter project was a spec to product project requiring only about four months to complete with a group of three people. This type of projects is ideal for interns because they can go through the whole product development process starting with specification analysis, feasibility study and preliminary researches to delivery of final product and providing firmware upgrades within their training period. In my case I got the chance to use the knowledge acquired in that project in two more projects.

This type of projects have their deadlines and limitations in availability of resources which makes work tough for developers. Since the group is small as three, the intern in the group also gets some responsibility and it helps the intern to feel the real industrial working conditions.

The amount of technological knowledge gathered in the project was enormous and that covered a vast range including fields such as video formats, video standards and video processing, analog circuit design, schematic and layout designing, firmware development, communication protocols, circuit testing and debugging. The technological knowledge gathered in these fields will be of great importance for my future projects. The fact that the first prototype didn't work at once and having to go through lot of debugging was a blessing in disguise kind of a factor for me, because it gave me a lot to learn. In addition to the large amount of knowledge and experience it was a good test of the temperament because the testing went on for weeks without much success.

The analog to HDMI converter project was a good chance for me to use the knowledge and skills acquired in the previous project. It gave me the opportunity to try out tactics learnt in the firmware development of the previous project. It was obviously easier than the previous project due to the knowledge I had gathered about video formats and standards and the skills I had improved in reading and understanding datasheets and design support files.

The RTL project (FPGA), HDMI transmitter module was a good choice by my instructor Mr. Kalana De Silva, because it had everything in the digital systems design process. It covered both implementation and synthesis flows and also gave the opportunity to touch debugging techniques such as implementing debug cores and using chipScope. This project gave me an overview of the digital designing process and brought me much required familiarity with that flow. This being my first project on zed board gave me a familiarity with the series of boards. It also gave me the confidence to take the challenge of developing a digital system in FPGA because now I have the experience in almost all the steps of the process.

As a whole, I can be very satisfied with the three projects I received because I had a lot to learn in all of them. Personally I can be satisfied with the amount of progress I made in all the three projects. Therefore I can conclude that the three projects I was involved in were ideal for an internship program.

Considering the fact that ParaQum Technologies is a startup company with a short history of about one year, it has done a great job providing a great training program for the interns. The company gave all the facilities required for a memorable stay at the company and assigned ideal projects for everyone considering their passionate areas as well. The engineers at the office are very much supportive and willing to corporate with trainees so that trainees have the chance to do their best. Therefore I can conclude that ParaQum Technologies is a great place for training for an electronic engineering undergraduate and the company have a good capability of providing a great training. If I observe anything to be improved is the amount of resources for research and development. I hope the company will improve on that and provide an even better training experience for interns next year.

3.4. Conclusion about the Industrial Training Program

We as undergraduates learn lot of theories and gather information thought out the four years. But most of us do not have any idea about how things are done in the industry, how projects are carried out, how products are manufactured and what kind of contribution we can put in to that process. This program gives solution to them all.

This program can be cited as the fastest learning period of the whole undergraduate life because it brought me a huge amount of knowledge, improved my skills, changed my attitudes as well as made me understand most of the theories that I had learnt just for the sake of passing examinations. Even for student who are hoping to proceed with higher education after graduation, this can be a very good experience because they see how the theories they knew are applied in the industry.

If not for this training program we would have to take a similar amount of time to take this experience when I go for an employment. That would seriously reduce the employability and also the quality of the degree. And also reduce the knowledge of the graduates because they will not know what the theories they learnt in the lectures are meant to be in applications.

Seeing how the industry functions and how projects are carried out in industry induces an entrepreneur mentality in an undergraduate and gives the confidence that they can be job providers rather than job seekers after graduation. I especially feel this because I worked in a startup environment seeing how a startup can thrive in a very short time since its inception.

The change of attitudes essential for the development of an undergraduate to the industry level is perfectly nurtured in this program.

Therefore I can conclude that the training program for undergraduates is a great opportunity for undergraduates and a great learning experience to improve themselves. Therefore I pay my sincere gratitude to NAITA and Industrial Training Division of University of Moratuwa for finding placements for undergraduates and helping all the way through.

3.5. Overall Assessment on Training Experience

When I was applying for a training program at ParaQum Technologies I was expecting to get some experience and knowledge on digital systems designing process. In the training period I was able to get full exposure to digital systems designing process and also several other fields such as analog circuit designing and firmware development. I was able to work on three projects in which I gathered a huge amount of technological knowledge and improved my skills. Since it is a startup I got the chance to contribute to products developed for outside clients. My contribution constituted large portions of the project giving me some responsibility also. I even gained the confidence to handle several parts of the projects such as firmware development alone.

Therefore I’m very much satisfied with the technological aspect of the training program.

In addition to the acquisition of knowledge and skills I was also able to identify several areas that I need to improve and concentrate more in the final year at the university. This will be useful for me in my future studies in university and outside.

Considering the exposure to the industry ParaQum offered much more than a startup. Therefore I can be satisfied with it although I could have had more exposure in a more established institution.

Getting to know how the industry operates I think I started the adaptation process to start a good career acquiring the most essential skills and knowledge.

Looking as a whole, I’m very much satisfied with my training experience at ParaQum Technologies and I can categorize it as one of the best possible training programs for and electronics undergraduate. It will be of great help for my future and I believe it laid a great foundation to start a career as an electronics engineer.