AN EFFICIENT COLOR SPACE CONVERSION USING XILINX SYSTEM GENERATOR

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Abstract: *In today's world there is enormous increase in 3D demand which is quite natural, as market is growing rapidly due to huge requirement of electronics media Humans will discern the depth illusion in a 3D image from two non-identical perspectives. The two viewpoints are from both the eyes provides an excellent immersive vision. The two different images are collectively called as a stereoscopic image and the whole process is called stereo image method.Stereoscopic 3D images are elementarily obtained by overlapping left and right eye images in different color planes of a single image for successive viewing through colored glasses. Here we present a novel reconfigurable architecture for 3D image color space conversion RGB to YCbCr by using 4:2:0 chroma subsampling method for implementing Digital image applications and compression of images ,low power low area using Xilinx System Generator (XSG) for MATLAB. And it is compared with the 4:2:2 chroma sub sampling method. The color space conversion (CSC) is implemented in Matlab simulink using xilinx block sets. Finally the Verilog code is generated using Xilinx system generator. This code is verified by Xilinx simulation tool for generating hardware requirement and power reports.*

Keywords-- ***CSC, FPGA, XSG, Simulink, Chroma subsampling***

I.INTRODUCTION

In today's world there is enormous increase in 3D demand which is quite natural, as market is growing rapidly due to huge requirement of electronics media Humans will discern the depth illusion in a 3D image from two non-identical perspectives. The two view points are from both the eyes provides an excellent immersive vision. The two different images are collectively called as a stereoscopic image and the whole process is called stereo image method.As the bandwidth requirement is very high when transmitting images in RGB color space there is a need to convert images into different color spaces such as YUV, YIQ and YCbCr and then transmitted.Depending upon the application and requirements the choice of the color space is chosen. In this paper we present a novel architectural module for efficient implementation of RGB to YCbCr color space conversion using an FPGA based system. Due to their low power dissipation per unit computation, high performance and re- configurability FPGAs are an attractive choice to implement.Color space is a complicated topic. Colors don't really exist, like dust does. We human being use colors to describe what we see. The most common way to describe what we see in terms of color is using combination of red, green and blue, which is referred as RGB color space. A color space is simply a model of representing what we see in tuples. YCbCr is one of the popular color space in computing and compression. It represents colors in terms of one luminance component/luma (Y), and two chrominance components/chroma(Cb and Cr). for storage and transfer the images and videos ycbcr is better because of having low bandwidth than the RGB colour space.

II. XILINX SYSTEM GENERATOR

Xilinx System Generator (XSG) [5] is an Integrated Design Environment (IDE) for FPGAs within the ISE 14.2 development suite, which uses Simulink [5], as a development environment and is presented in the form of model based design. Here Designs are modeled and simulated using MATLAB Simulink and Xilinx library and the tool automatically generates the HDL code that is to be mapped into pre- optimized Xilinx blocks in the design. There is a connection between XSG blocks and Simulink blocks i.e., gateway blocks. XSG automatically generates simulation results, RTL synthesis, VHDL/Verilog code, User Constraint File (UCF) and mapping hardware. It was created primarily to deal with complex Digital Signal Processing (DSP) applications but now it is intensively used for the implementation of many image processing applications.Xilinx System Generator provides a set of Simulink blocks (models) for several hardware operations that could be implemented on various Xilinx FPGAs. These blocks can be used to simulate the functionality of the hardware system using Simulink environment. The XSG Design flow is as shown in Figure 1.In addition, the software provides for the hardware simulation and hardware-in-the-loop verification, referred to as hardware co-simulation [2,3], from within this environment. For easier hardware verification and implementation compared to HDL based approach we use hardware co-simulation methodology. When compared in terms of cost efficiency the usage of Simulink simulation and hardware-in-the loop approach is far better than other methodologies.

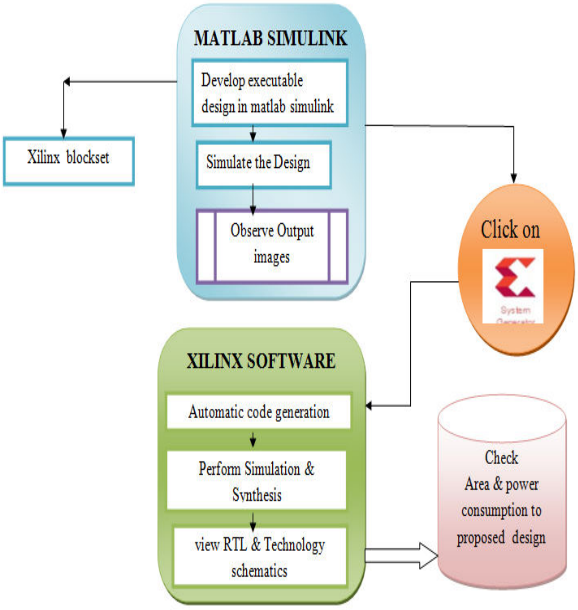


Fig1: The XSG Design flow

III.RELATED WORK

A color space is all possible colors that can be made from a group of colourants, Imagine, for example, shining three lights together onto a white wall: one red light, one green light, and one blue light, each with dimmer switches. If only the red light is on, the wall will look red. If only the green light is on, the wall will look green. If the red and green lights are on together, the wall will look yellow. Dim the red light some and the wall will become more of a yellow-green. Dim the green light instead, and the wall will become more orange. Bringing up the blue light a bit will cause the orange to become less saturated and more whitish. In all, each setting of the three dimmer switches will produce a different result, either in color or in brightness or both.

Digital cameras and scanners and create images using combinations of just three colors: Red, Green and Blue (RGB). These are the primary colors of visible light and this how computers and televisions display images on their screens. RGB colors often appear brighter and more vivid specifically because the light is being projected directly into the eyes of the viewer.

RGB COLOR SPACE

An RGB color space is all possible colors that can be made from three colourants for red, green and blue. All color spaces can be derived from the RGB information supplied by devices such as cameras and scanners.

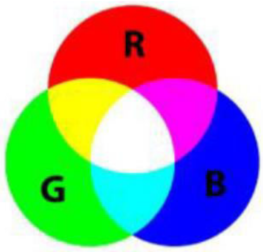


Fig:2 RGB Colour Space

But medical research proved that the human eye has different sensitivity to colour and brightness. Study shows human eyes are sensitive to luminance, but not so sensitive to chrominance. Thus there came about the transformation of RGB to YCbCr. According to Medical investigation, the eye has led to findings that the *rods* some 120 million in number, are much more sensitive than the *cones* which are around 6-7 million in number. The rods are not sensitive to colour, while the cones which provide much of the eye's colour sensitivity are found to be located close to a central region called the *macula*.so the human can feel stress to eyes when choose a high amount of colour because of less number of cones.The intension of this project is to reduce the colour information for efficient transmission and storage.

INTERNAL STURCTURE OF HUMAN EYE

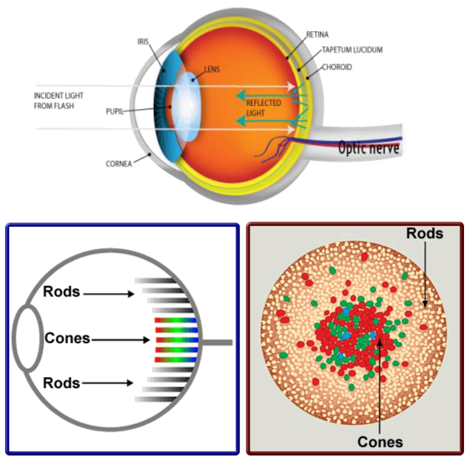


Fig 3:Internal structure of eye- presence of Rods and Cones

In order to overcome the drawbacks of RGB colour space conversion we are going to impelement the YCbCr colour space conversion.In this ycbcr 4:2:2 have high band width, more area and high power consumption.Here we are implementing YCbCr 4:2:0 for reducing Size of the images, area and power consumption.

COLORSPACE CONVERSION

Color Space Conversion (CSC) [6] is the mathematical translation of the numerical representation of a color from one color cube definition to the other. In most of the videos there is a full bandwidth of RGB signals that were not determined to be to be economically efficient enough as a means for storage and broadcasting. That's why RGB signals are encoded to YCbCr , where primary colors red,blue, green are proceesed into images that closely resemble the original RGB image , but at a much lower bandwidth for transmission. In YCbCr space, an image is represented by one luma (Y) and two chroma (Cb, Cr) components. The luma channel contains brightness information; it is essentially a grey scale version of the image and the chroma values are color offsets. In YCbCr space, the bandwidth of an image tends to be concentrated in the Y Channel. This leaves the Cb and Cr channels with less information, so they can be represented with fewer bits.The human eye doesn't actually see equally well in the different color bands with our human vision [9] system optimized for the red, green bands but not quite as sensitive to changes in blues.Scientist and engineers looking for ways to reduce the bandwidth and/or bit rate of a videos and images have created other color spaces Therefore, many video systems sub sample the color information [9] (chrominance) while transmitting the black and white (luminance) in full resolution. This subsampling is often applied to luminance chrominance color space systems such as YCbCr where Y re presents the luminance information and Cr and Cb are color difference signals that represent the chrominance information. In these systems all of the Y samples are used but every other color sample is dropped.

CHROMA SUBSAMPLING

Chroma subsampling is the practice of encoding images by implementing less resolution for chroma information than for luma information, taking advantage of the human visual system's lower acuity for color differences than for luminance. Because the human visual system is less sensitive to the position and motion of color than luminance, bandwidth can be optimized by storing more luminance detail than color detail.The subsampling scheme is commonly expressed as a three part ratio *J*:*a*:*b* (e.g. 4:2:2) , that describe the number of luminance and chrominance samples in a conceptual region that is *J* pixels wide, and 2 pixels high. The parts are (in their respective order):

- *J*: horizontal sampling reference (width of the conceptual region). Usually, 4.
- *a*: number of chrominance samples (Cr, Cb) in the first row of *J* pixels.
- *b*: number of changes of chrominance samples (Cr, Cb) between first and second row of *J pixel*

IV.EXISTING METHOD

YCbCr Color Space with 4:2:2 chroma subsampling was developed as part of the Recommendation ITU R BT.601 [1] (International Telecommunication Union) for worldwide digital component video standard and is used in television transmissions. In this color model, the luminance component is separated from the color components. Component (Y) represents luminance, and chrominance information is stored as two color difference components. Color component Cb represent the difference between the blue component and a reference value and the color component Cr represents the difference between the red component and a reference value [1]. The basic equations to convert between RGB and YCbCr are:

$$\begin{bmatrix} Y \\ C_R \\ C_B \end{bmatrix} = \begin{bmatrix} CA & 1-CA-CB & CB \\ CC(1-CA) & CC(CA+CB-1) & CC(-CB) \\ CD(-CA) & CD(CA+CB-1) & CD(1-CB) \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where CA,CB ,CC,CD are the Co-efficients actual values for CA and CB differ slightly in different standards.(CA=0.299, CB=0.114 , CC=1/(2(1-CA)), and CD=1/(2(1-CB)) according to ITU).

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.58 \\ 0.5 & -0.41 & -0.081 \end{pmatrix} * \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$\begin{bmatrix} Y \\ C_R \\ C_B \end{bmatrix} = \begin{bmatrix} CA & 1-CA-CB & CB \\ CC(1-CA) & CC(CA+CB-1) & CC(-CB) \\ CD(-CA) & CD(CA+CB-1) & CD(1-CB) \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} O_Y \\ O_C \\ O_C \end{bmatrix}$$

Where constants OY and OC facilitate offset compensation for the resulting Y, CB and CR components.

OY (YOFFSET) =2^($OWIDTH$-4) = 16

OC(COFFSET)=2^($OWIDTH$-1)=128

where ($OWIDTH$=8 (422=4+2+2))

Then the offset values of the luma and chroma are given in the below matrix

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.58 \\ 0.5 & -0.41 & -0.081 \end{pmatrix} * \begin{pmatrix} R \\ G \\ B \end{pmatrix} + \begin{pmatrix} 16 \\ 128 \\ 128 \end{pmatrix}$$

from the above matrix the equations of Y,Cb,Cr are

$$Y = 0.299R + 0.587G + 0.114B + 16$$
$$Cb = 0.169R–0.331G + 0.5B + 128$$
$$Cr = 0.5R–0.419G–0.081B + 128$$

Among all the color models found, YCbCr seems to be better because humans are sensitive to brightness information than color information which is more in luminance (Y channel) when compared to chrominance (Cb and Cr channels). During video processing the luminance can be removed by converting the image from RGB color model to the Y CbCr color model [1]. The signal is divided into a luma (Y') component and two color difference components (chroma).

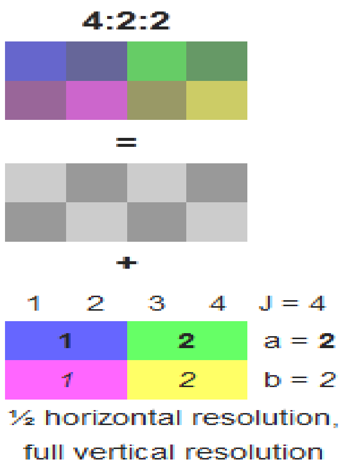


Fig 4:Colour Sharing Concept in YCbCr 4:2:2

Full resolution luma, and half resolution chroma horizontally on the chroma components. The 4:2:2 chroma sampling, samples two pixels from both the top and bottom rows.Even performing the ycbcr 4:2:2 chroma subsampling the bandwidth of the image is more so there is another improvement technique in chroma sub sampling that is ycbcr 4:2:0.

V.PROPOSED METHOD

This subsampling is often applied to luminance-chrominance color space systems such as YCbCr where Y represents the luminance information and Cr and Cb are color difference signals that represent the chrominance information. In these systems all of the Y samples are used but every other color sample is dropped. These systems are referred to as 4:2:0 sampling.The 4:2:0 nomenclatures signify that for every 4 Y samples only 2 Cb and 0 Cr samples are saved. The more reduced 4:2:0 sampling takes two chroma samples from the top “a” row of pixels and none from the bottom “b” row. Instead, the bottom row shares choma information from the top row sampling.

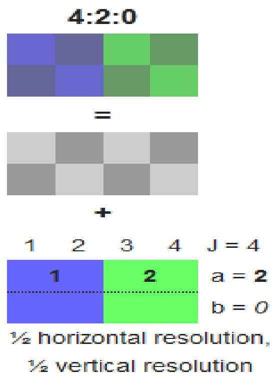


Fig 5:Colour Sharing Concept in YCbCr 4:2:0

Owing to the bandwidth saving benefits of these different image formats different video equipment will adopt different color space encodings. Interoperability between such equipment often requires a device to convert the output of one video device in a given color space to the color space needed as input for the downstream device.YCbCr Color Space was developed as part of the Recommendation ITU-R BT.601 [1] (International Telecommunication Union) for worldwide digital component video standard and is used in television transmissions. In this color model, the luminance component is separated from the color components. Component (Y) represents luminance, and chrominance information is stored as two color difference components. Color component Cb represent the difference between the blue component and a reference value and the color Component Cr represents the difference between the red component and a reference value [1].

The basic equations to convert between 4:2:0 YCbCr Chroma subsampling are:

$$\begin{bmatrix} Y \\ C_R \\ C_B \end{bmatrix} = \begin{bmatrix} CA & 1-CA-CB & CB \\ CC(1-CA) & CC(CA+CB-1) & CC(-CB) \\ CD(-CA) & CD(CA+CB-1) & CD(1-CB) \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} O_Y \\ O_C \\ O_C \end{bmatrix}$$

Where CA,CB ,CC,CD are the Co-efficients actual values for CA and CB differ slightly in different standards.(CA=0.299, CB=0.114 , CC=1/(2(1-CA)), and CD=1/(2(1-CB)) according to ITU).and constants OY and OC facilitate offset compensation for the resulting Y, CB and CR components.

For 4:2:0 CHROMA SUBSAMPLING:

OY (Y Offset)=2^(*O Width*-4) = 4

OC(OCOffset)=(2^(*OWidth*-1))*6+2^(*Owidth-1)* *=224*

where (*OWIDTH=6(420=4+2+0*)

From the above calculation the ycbcr 4:2:0 ratio equations are derived as follows

$$\begin{pmatrix} Y \\ Cb \\ Cr \end{pmatrix} = \begin{pmatrix} 0.299 & 0.587 & 0.114 \\ -0.169 & -0.331 & 0.58 \\ 0.5 & -0.41 & -0.081 \end{pmatrix} * \begin{pmatrix} R \\ G \\ B \end{pmatrix} + \begin{pmatrix} 4 \\ 224 \\ 224 \end{pmatrix}$$

From the above matrix the equations for Y,Cb,Cr

$$Y = 0.299R + 0.587G + 0.114B + 4$$
$$Cb = 0.169R – 0.331G + 0.5B + 224$$
$$Cr = 0.5R – 0.419G – 0.081B + 224$$

Among all the color models found, YCbCr 4 : 2 : 0 seems to be better because humans are sensitive to brightness information than color information which is more in luminance (Y channel) when compared to chrominance (Cb and Cr channels). During video processing the luminance can be removed by converting the image from RGB color model to the YCbCr color model [1].

IMPLEMENTATION AND SIMULATION RESULTS

The model uses the top level HDL module and its Xilinx blockset for RGB to Y, Cb, and Cr components as shown in Figure 2. This model is used for co-simulation i.e.,simulation in Matlab and the generated code from the system generator. Once the design is verified, a hardware co- simulation block is generated and it will be used to program the FPGA for the CSC design implementation.The CSC deign is shown in following figure.

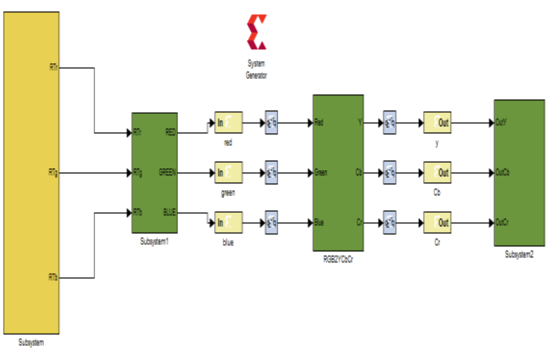
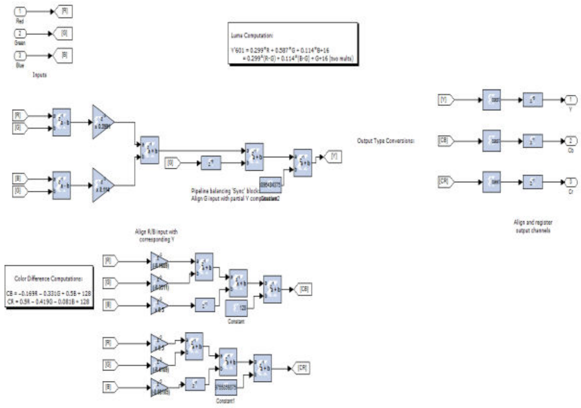
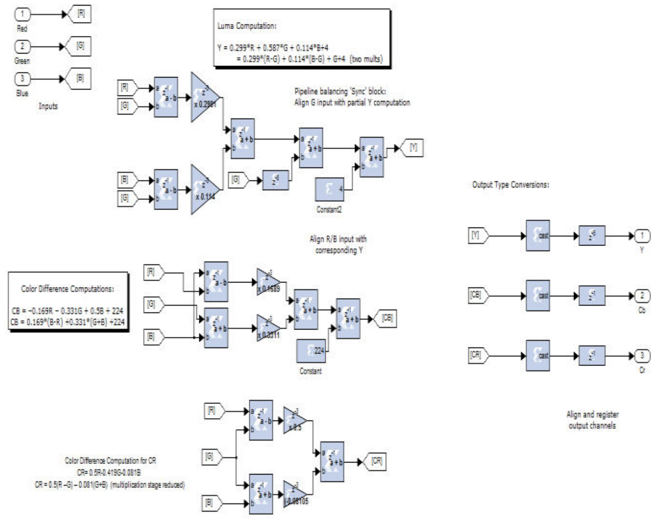


Fig6: RGB to YCbCr CSC subsystems design

INTERNAL STRUCTURE OF YCbCr 4:2:2



INTERNAL STRUCTURE OF YCbCr 4:2:0



MATLAB SIMULINK RESULTS

For Existed method

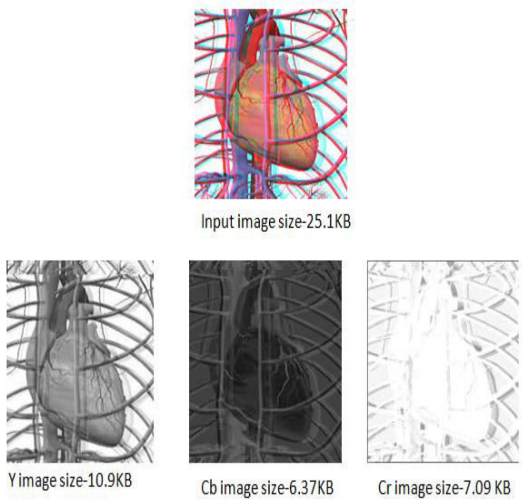
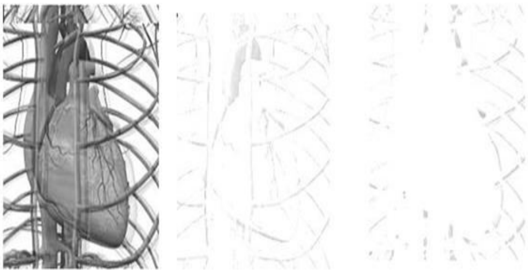


Fig7: Output images for 4:2:2 RGB to YCbCr

For Proposed method

The matlab simulink results for RGB to YCbCr colour space conversion are shown.From the below images the sizes of the Cb,Cr images in existing method are reduced while using the proposed method.This reduction of image size shows the image compression.The luma inoformation of both existing and proposed method have same size.



Y-IMAGE SIZE -10.9KB Cb - IMAGE SIZE-4.0KB Cr- IMAGE SIZE-2.9KB

Fig8: Output images for 4:2:0 RGB toYCbCr

XILINX RESULTS

DEVICE UTILIZATION (Hardware - requirement)

For YCbCr 4:2:2 chroma subsampling:

Device Utilization Summary (estimated values)		
Logic Utilization	Used	Available
Number of Slice Registers	303	407600
Number of Slice LUTs	165	203800
Number of fully used LUT-FF pairs	98	370
Number of bonded IOBs	61	500
Number of BUFG/BUFGCTRLs	1	32

For YCbCr 4:2:0 chroma subsampling

Device Utilization Summary (estimated values)		
Logic Utilization	Used	Available
Number of Slice Registers	219	407600
Number of Slice LUTs	133	203800
Number of fully used LUT-FF pairs	77	275
Number of bonded IOBs	61	500
Number of BUFG/BUFGCTRLs	1	32

The above tables shows the synthesis reports of existed and proposed method using xilinx 14.2 .In these the number of slice registers and slice LUTS and flipflops are reduced in proposed YCbCr 4:2:0 chroma sub sampling.This reduction shows the reduction of hardware requirement for proposed method.

TARGET FPGA BOARD DETALS

Device	
Family	Kintex7
Part	xc7k325t
Package	ffg900
Temp Grade	Commercial
Process	Typical
Speed Grade	-2
Environment	
Ambient Temp (C)	25.0
Use custom TJA?	No
Custom TJA (C/W)	NA
Airflow (LFM)	250
Heat Sink	Medium Profile
Custom TSA (C/W)	NA
Board Selection	Medium (10"x10")
# of Board Layers	12 to 15
Custom TJB (C/W)	NA

Here we are using a target FPGA board is Kintex7.The details of the board is as shown in above.This can be generated in Power report only in implementation of YCbCr colour space conversion. Because of highly expensive the hardware of fpga board is not directly used in place of this target fpga can be used with in xilinx system generator.

POWER REPORTS

FOR EXISTING METHOD

On-Chip	Power (W)	Used	Available	Utilization (%)
Clocks	0.005	1	---	---
Logic	0.000	704	203800	0
Signals	0.001	1066	---	---
IOs	0.005	61	500	12
Leakage	0.122			
Total	0.133			

FOR PROPOSED METHOD

On-Chip	Power (W)	Used	Available	Utilization (%)
Clocks	0.003	1	---	---
Logic	0.001	589	203800	0
Signals	0.001	882	---	---
IOs	0.005	61	500	12
Leakage	0.122			
Total	0.132			

The above power reports are generated using Xilinx software those are shown in above tables.In these the power consumption of existing method is 133 milli watts these can reduced 132 milli watts in proposed method.

COMPARISON TABLES
IMAGE SIZE COMPARISON

IMAGE	EXISTED IMAGE SIZE	PROPOSED IMAGE SIZE
Y-Image	10.9KB	10.9KB
Cb-Image	6.37KB	4.07KB
Cr-Image	7.09 KB	2.99KB

COMPARISON OF RESOURCE UTILIZATION REPORT IN THE IMPLEMNTATION OF CSC DESIGN

Name of the componen t	Existing Method		Proposed Method	
	Resou rces Used	Device Usage	Resou rces Used	Device Usage
No. Of slice registers	303	0%	219	0%
No. Of Slice LUTs	165	0%	133	0%
No. Of fully used slice flipflops	98	26%	77	27%
No. Of fully used LUT-FF pairs	614	72%	524	76%
No. Of unused Flipflops	80	9%	70	10%
No. used as memory	236	1%	187	1%

COMPARISON OF POWER CONSUMPTION

EXISTING METHOD POWER(mW)	PROPOSED METHOD POWER(mW)
133mw	132mw

CONCLUSION

The design is implemented using XSG and Simulink IDE.By this colour space conversion image size will reduces auotomatically storage capacity wiil becomes low . It is less complex and highly flexible for prototyping and modifications. It is implemented with MatLab12a version and Xilinx ISE 14.2. The implementation of CSC design of 3D image is very high in terms of accuracy in image size compression and low hardware requirement and the less power consumption. Obviously, our proposed architecture has lowered complexity and area is improved efficiently, thus providing a good choice in terms of low-cost hardware.

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BIOGRAPHY

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She is persuing M.Tech with Department of VLSI System Design in Annamacharya Institute of Technology and Sciences, Rajampet. Her research interests in 3D Colour Space Conversion and impementation of results through VLSI domain.

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