Test System for Evaluation of Spacecraft Command Distribution Hardware

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Abstract

Telecommand system is a vital link between ground station and on-board system. In order to carry out the comprehensive testing of command distribution hardware that decodes and generates pulse/level signals to command the subsystem in Spacecraft, it is necessary to have a testing unit. This paper deals with development of test platform for testing, evaluating and qualifying a new Application Specific Integrated Circuit design for telecommand distribution. Test platform can test both the card level and package level of telecommand package. Test platform can be able to test the Telecommand system thoroughly, providing the required stimulus and capturing all the responses of the system. Test platform evaluates the new Application Specific Integrated Circuits by providing the capability to generate exhaustive test cases for positive and negative test. It also caters for testing all the future command distribution cards realized using the new Application Specific Integrated Circuit. The test platform is to detect and acquire the commands from on-board hardware and evaluate its performance. This paper describes the design and development of test platform in detail.

Keywords: Telecommand, Spacecraft, ASIC, testing unit.

1. INTRODUCTION

Spacecrafts are remotely controlled from ground for carrying out the planned mission operations. Telecommand Systems play a critical role in these operations by performing the functions of receiving, decoding, validating and execution of commands. Execution normally involves the process of decoding, demultiplexing and forwarding the commands to various subsystems, is usually referred as Command Distribution. Commands can be conveyed to sub systems in the form of electrical pulse or as data. Pulse, Level and Fixed length Serial Data Commands are categorized under Discrete Command Interfaces. These are the most abundantly used interfaces in any spacecraft and constitute the bulk of Telecommand Hardware. Several types of hardware designs have been realized to distribute discrete commands using a combination of ASICs, FPGAs and Discrete ICs.

2. A BRIEF ON SPACECRAFT SYSTEMS

A modern Spacecraft contains two major systems, the Bus System and the Payload System. The Bus System is an ensemble of mainframe subsystems that work for maintaining the operational environment required for the payload systems to carry out their functions. They include the equipment for orbit and attitude control, power generation, storage, regulation and distribution, thermal management, propulsion and telemetry, tracking and command. Payload Systems contain the equipment to achieve the desired functions of the spacecraft that it has been built for.

Spacecraft Systems have to be controlled and monitored from ground throughout its life. For carrying out these functions, Telecommand Subsystem plays a vital role by bridging the communication between the Mission Control Center on ground and the Spacecraft in orbit. Under normal conditions, this subsystem maintains the health of the spacecraft and carries out payload operations to service the user community. In case of emergency, it also performs recovery operations and keeps the spacecraft in survival mode until the next ground contact.

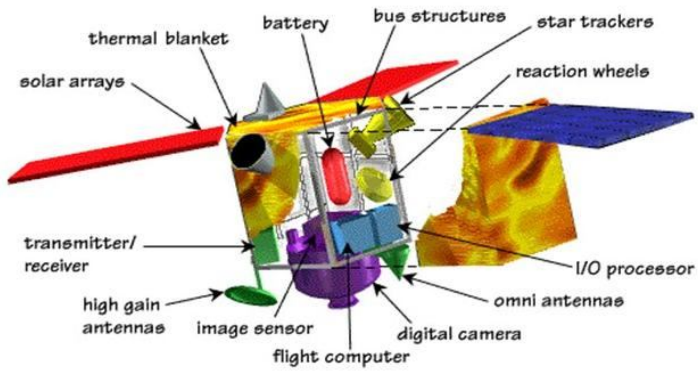


Figure 1 Subsystem in a Spacecraft

2.1 Telecommand – A Critical Spacecraft Subsystem

Telecommand Systems are extremely critical for operation and maintenance of the spacecraft. They have to be always agile in receiving the commands from ground at any time and execute them with high degree of certainty. To satisfy this condition, Systems involved in sourcing, routing, uplinking, reception and processing and processing of Telecommands have to be designed to make them available 24x7, offering minimal rejection and near zero spurious. In a nutshell, the Spacecraft Telecommand Systems have to be designed for robustness and availability.

2.2 Major modules of a Spacecraft Telecommand System

Spacecraft Telecommand Systems are usually realized with dual hot redundancy for performing functions related to command decoding, distribution, onboard automation and autonomy. As shown in Figure 2, the major modules involved in carrying out these operations are

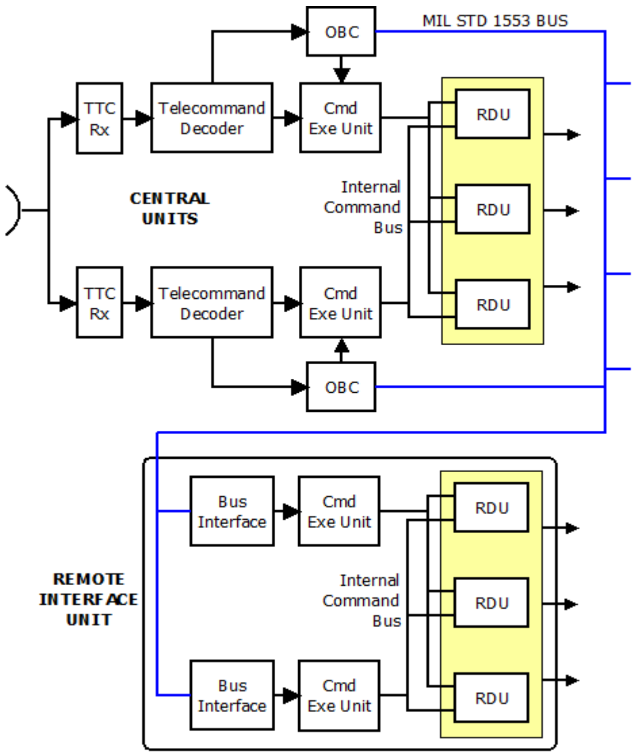


Figure 2 Block diagram of a Spacecraft Telecommand System

- Telecommand Decoder
- Onboard Computers (OBC)
- Command Execution Unit
- Command Distribution Unit

2.2.1 Telecommand Decoder

Telecommand Decoders are the front end of a Telecommand system. They identify, decode, validate and execute the commands contained in the incoming bit stream from Command Receivers. For carrying out these functions, they employ Frame Synchronization Techniques, Channel Decoding and Command validation protocols. Telecommand Decoders are implemented in Space qualified hardware like FPGAs and ASICs.

2.2.2 Onboard Computers

Onboard Computers in modern spacecrafts play a major role in operating the spacecraft autonomously with minimal ground intervention. The software designed to run on these computers implement several functions like sequencing of Payload operation, Time Tagged Commanding, Event Based Commanding, Battery Management, Fault Detection, Isolation and Recovery etc. The software can be programmed in various modes of operation from ground to cater to the variety of operational requirements during various phases of a mission.

2.2.3 Command Execution Unit

Command Execution Unit CEU accepts ground commands from Telecommand Decoder or stored commands from Onboard Computer, initiate execution by transferring command data followed by a Master Pulse over a serial/parallel bus to Command Distribution Units (CDU). The Command Distribution Units decode the data and transfer the master pulse on one of the outputs as per address contained in the data. For centralized distribution, CEU is implemented as a part of Telecommand Decoder. For a decentralized distribution, the CEU is implemented as a part of Remote Interface Units that communicate with the OBC using standard bus interfaces like MIL STD 1553, CAN Bus etc.

2.2.4 Command Distribution Unit

Command Distribution Unit is the hardware entity that receives the command data and master pulse, operates on the received data to select the channel for routing the Master Pulse. They are usually realized using FPGAs, ASICs, and Discrete ICs for Digital logic implementation and Relays, MOSFET switches for power switching.

For distributing discrete commands, a network of CDUs is connected to Nominal and Redundant Command Execution Units through Internal Command Bus. At a given instant, one CEU can send commands to any of the CDUs. Each CDU has a unique hardwired address assigned and executes the commands only when the incoming address in command matches with the hardwired address. Command Distribution Units are either a part of central units or in Remote Interface Units. Remote Interface Units receive the commands over MIL STD 1553 Bus from OBCs for execution.

2.3 Command Distribution Interfaces

The most basic form of commanding a subsystem is sending an electric pulse of some fixed duration or setting a Level to make them ON/OFF. In certain cases, short data commands are serially transmitted to the destination systems for performing more complex operations. Pulse, Level and Data Command interfaces are the most essential basic interfaces that are abundantly used in spacecrafts. A variation in Pulse Command Interface is Switch Matrix Interface wherein a row-column decoding approach is followed instead of flat decoding.

Figure 3 illustrates the discrete command interfaces. Either the Telecommand Decoder or the Onboard Computer loads the command to CEU. When executing, one of the CEUs places the data and Master pulse over Internal Command Bus carrying the signals to Command Distribution Network. The Command Distribution Unit implements the demultiplexing function to route the Master Pulse to the destination subsystem or set/reset an internal flip-flop to generate a level for the destination subsystem. A pulse or a level signal is routed to the subsystem using various types of electrical interfaces like single ended CMOS interface, High Voltage Interface, Differential Interfaces like 422 etc. These interfaces are used to switch subsystems ON or OFF, select some operating modes or operate heaters.

Data command interfaces usually carry data, clock and transfer pulse signals to the subsystem for conveying short data messages (16 or 32 bits) to the subsystems. These interfaces are used when subsystem requires low level programming or for internal decoding of multiple pulse commands.

Switch Matrix Command interfaces are used to drive Relay Matrices. The row column arrangement minimizes the drivers for energizing coils. A latching relay in the matrix outputs high voltage levels and a non latching relay outputs high voltage pulses.

Bulk Data Interfaces use On-board Network like MIL-STD-553 Bus Interfaces (See Figure 2), CAN bus etc. These are used to transfer data for carrying out complex functions like reprogramming or configuring the subsystems in various modes of operation.

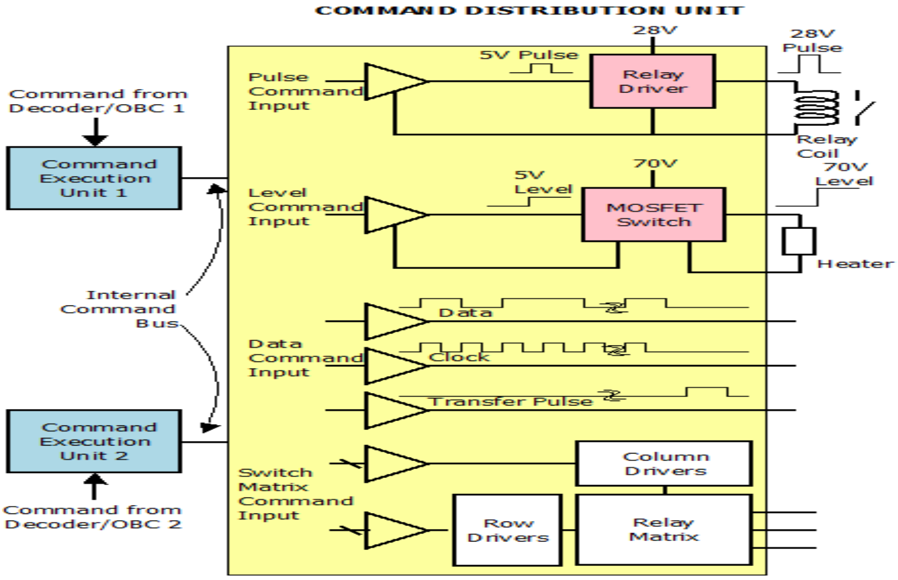


Figure 3 Discrete Command Interfaces

3. DESIGN

A test system design requires the knowledge and experience of multiple fields. The test system design comprises of both hardware design and Software Design. Based on the literature studies carried out on various test system architectures to test, analyze, characterize and to space qualify the product test system architecture is proposed here. The test system is a PC based test system with simple hardware and software subsystem modules for easy portability and testability. The conceptual diagram of the proposed test system configuration is described in below figure.

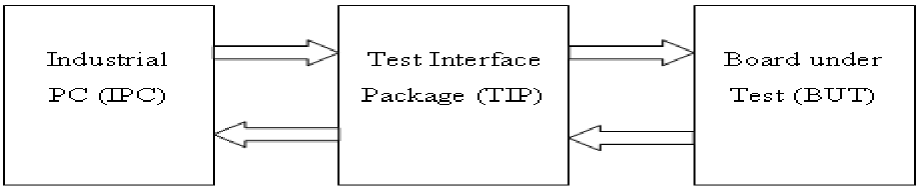


Figure 4 Block diagram of Test Sytem

Where

1. Signals from IPC to TIP - Clk, Data, Window, Pulse, TM Clk, TM SA, TM P/S
2. Signals from TIP to IPC - Opto isolated and Buffered Clk, Data, Window, Pulse TM Clk, TM SA, TM P/S
3. Signals from TIP to BUT – TM Data
4. Signals from BUT to TIP – OptoIsolated and Buffered TM Data

3.1 Industrial PC

Industrial PC(IPC) mounted in Rack and populated with Digital IO Card

- DYNALOG (INDIA) Ltd.
- RACK 300GW-R20(2 × 320GB)
- Intel CoreDuo e7500 @ 2.93GHz
- DIGITAL INPUT/OUTPUT CARD – SPARTAN3 Xilinx Based PCI9054 Hardware Simulation Board

GUI is designed in such a way that maximum amount of selection or information can be given to the user. Application software is required to carry out functions/operations from GUI. The software reads the data from the GUI and generates the executable test file. Device driver provides an interface between the Operating System and hardware device. In I/O interface card VHDL coding takes place for telecomm and telemetry. Add on card is also there in PC, through which communication between TIP and computer takes place.

3.2 Test Interface Package

Test interface Package is used to interface the PC with add on card to the onboard package. The functions of the test interface package to receive the simulated signals from the PC and route it to the Board under Test and to receive the response from the Board Under test with the test station. This necessary to protect the board containing space grade components from any malfunctioning of power supplies in Test system IPC.

3.3 Board Under Test

Board under test contains the Command Distribution ASIC with supporting digital and passive components. The board works at 5V and takes a quiescent current of 2mA. All the inputs from outside to ASIC are buffered using HC4050 cold sparing buffers. All the outputs from the ASIC are brought out using a 1 K ohm resistor to protect the ASIC pins from short circuit stress. The test system signals from TIP Package are interfaced to this board for commanding and status monitoring. All the command outputs are monitored using an oscilloscope.

4. RESULTS

The VHDL code of a top-level module which contains the telecommand system. The simulation results can be seen to match the input to the code (written in c++).
The design was synthesized and implemented in Libero IDE 9.1v. The synthesis report of the system generated by synplify for target FPGA Actel ProASIC A3PE3000 are shown below.

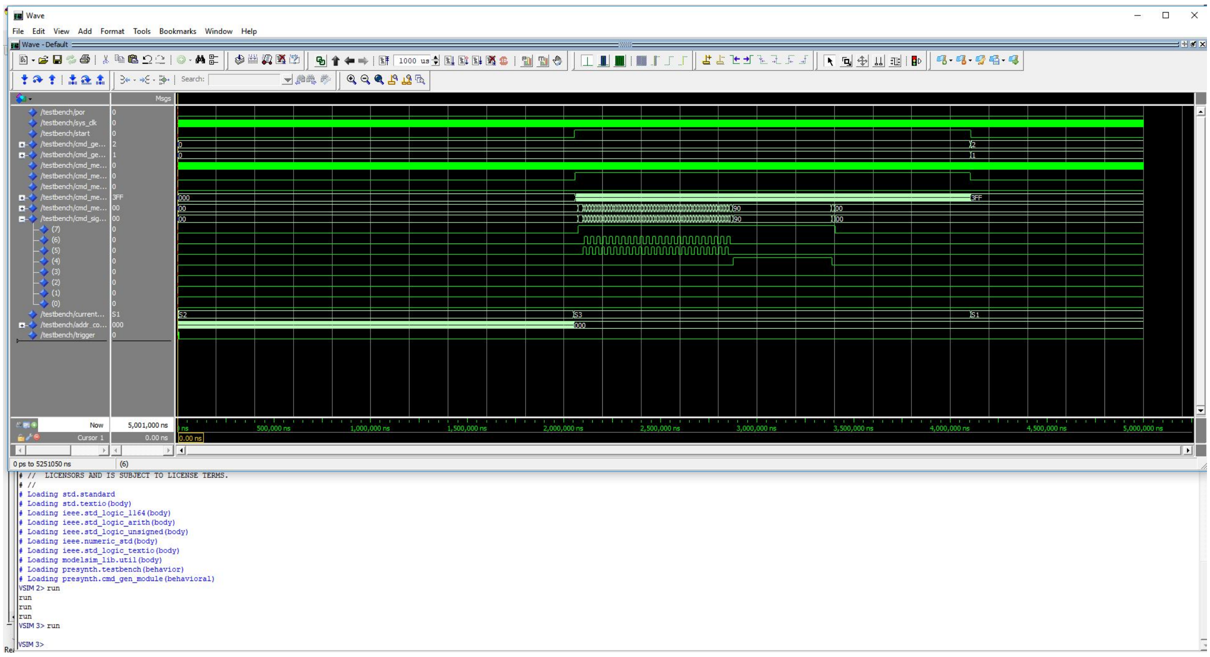


Figure 5 simulation results for 32 bit format

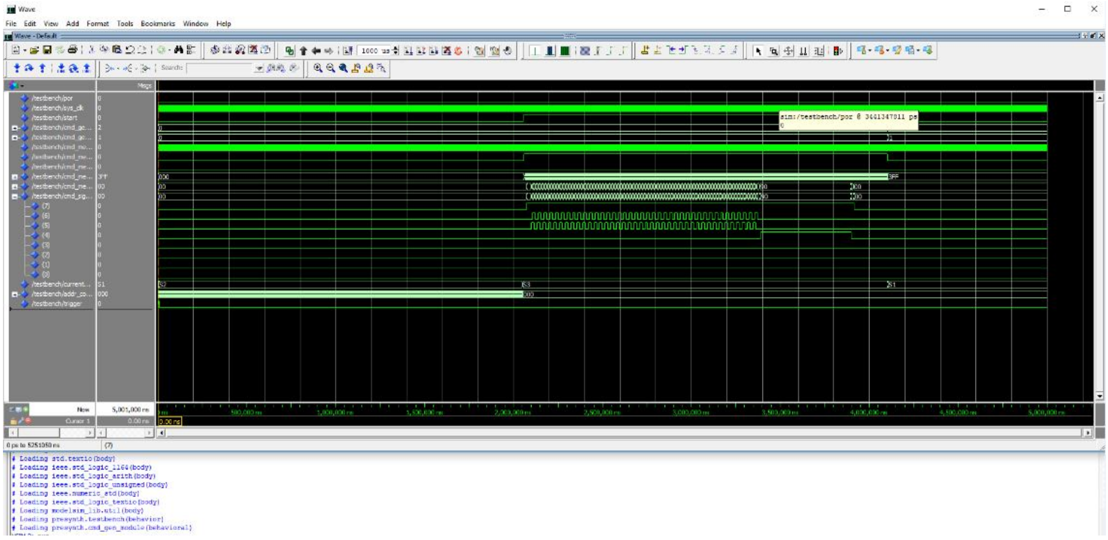


Figure 6 Simulation results for 48 bit command format

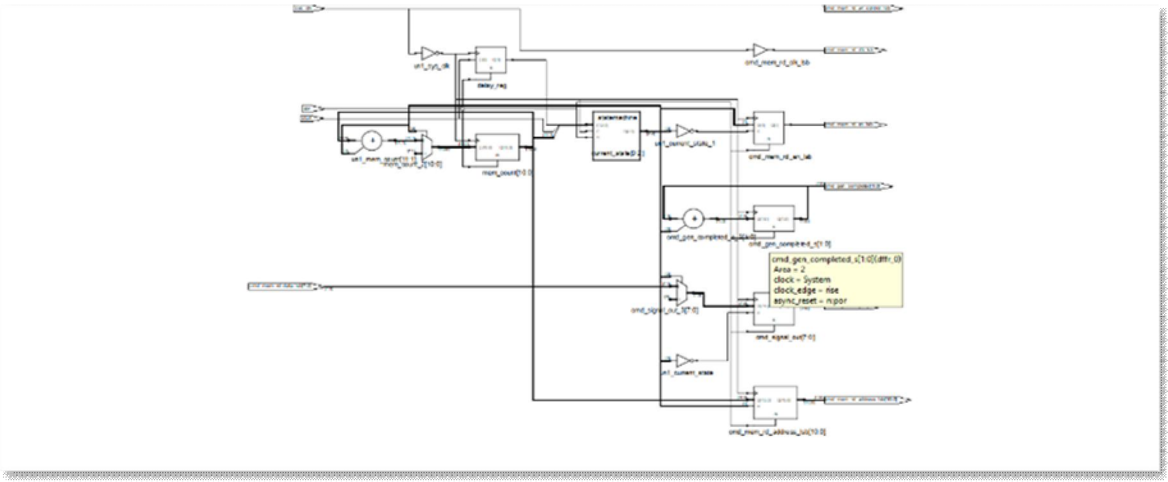


Figure 7 RTL View

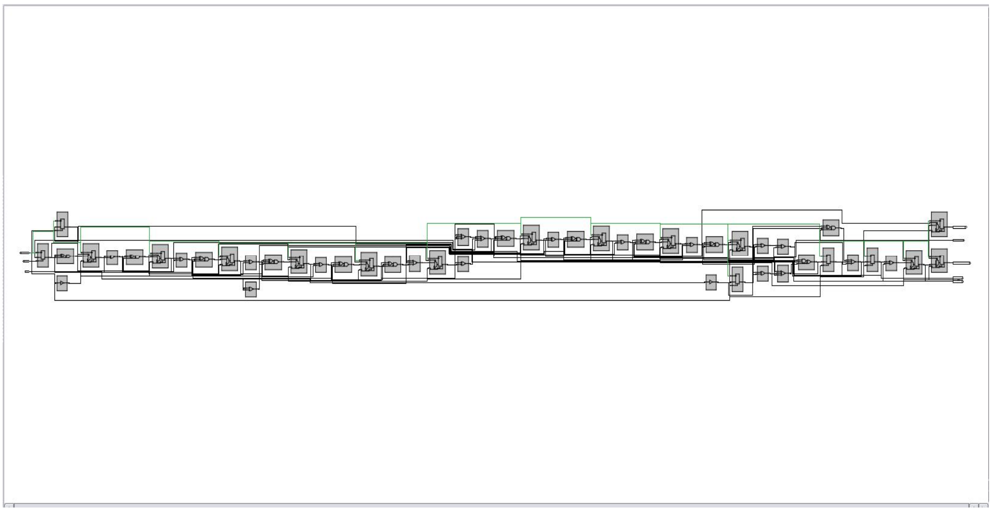
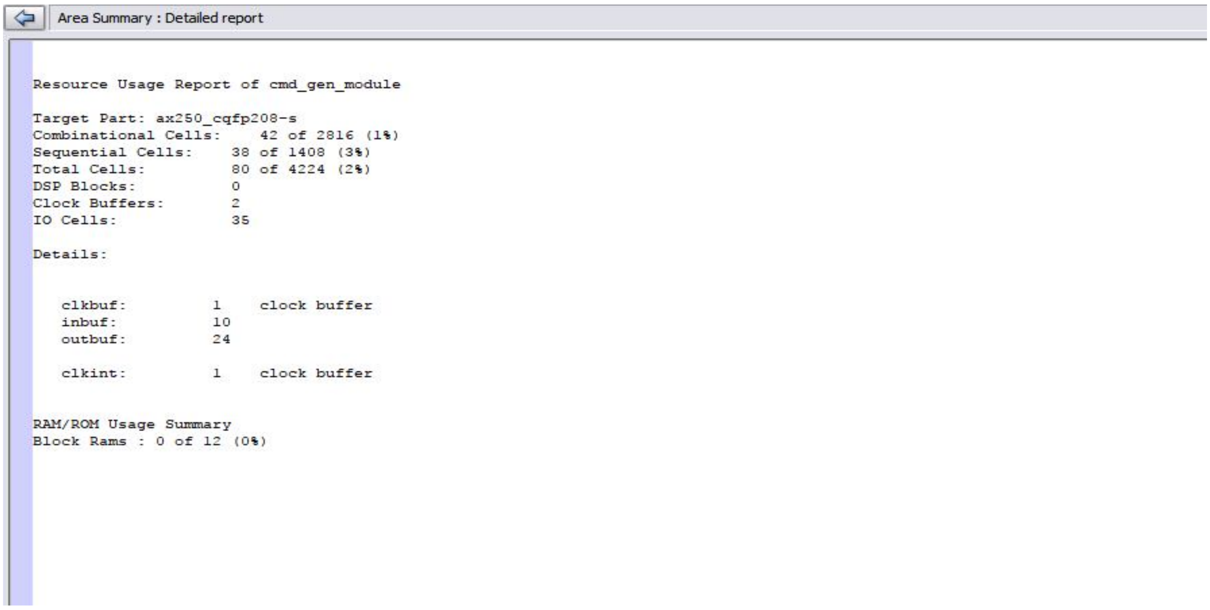


Figure 8 Technology View



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Area Summary : Detailed report

Resource Usage Report of cmd_gen_module

Target Part: ax250_cqfp208-s
Combinational Cells:    42 of 2816 (1%)
Sequential Cells:      38 of 1408 (3%)
Total Cells:           80 of 4224 (2%)
DSP Blocks:            0
Clock Buffers:         2
IO Cells:              35

Details:

    clkbuf:          1    clock buffer
    inbuf:           10
    outbuf:          24

    clkint:          1    clock buffer

RAM/ROM Usage Summary
Block Rams : 0 of 12 (0%)
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Figure 9 Area report

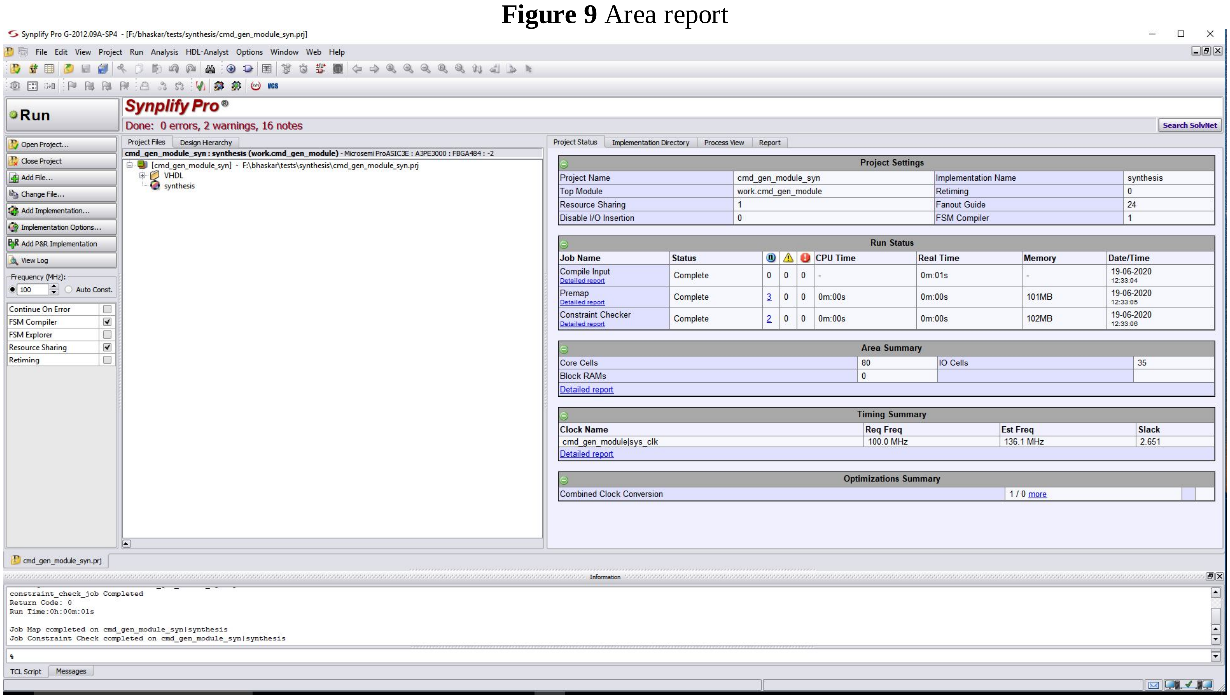

Figure 10 Design Utilization Summary

5. CONCLUSION

The Test system developed is faster, more efficient and more user friendly as compared to earlier test systems. It is Versatile and can be used with a lot of project with minor changes in the software or hardware design. It evaluates the new ASIC by providing the capability to generate exhaustive test cases for positive and negative test. It caters for testing all the future command distribution cards using the new ASIC.A new command structure to support all the functionalities of the distribution scheme was discussed.

Based on the new scheme, a composite command distribution board has been realized that provides more command capacity. This will further enhance the capabilities of the command distribution hardware. Thus, it provides a promising solution for realizing the more reliable Command Distribution Hardware with reduced weight and volume.

6. ACKNOWLEDGEMENT

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