

# Automated Test Station for Validation of Satellite Electronic Subsystems

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**Abstract** - The Telecommand System has to be tested to check if it is working as per requirements before putting it onboard. The Telecommand Test Station simulates and provides all the signals required by the Telecommand hardware system and monitors all types of outputs by scanning for spurious operations. The Test Station is automatic in the sense that a set of commands can be issued and performance is monitored and verified without operator intervention. In order to achieve this, there is a need to generate command input and also Telemetry Control Signals to the Unit Under Test and then measure the responses. All the above mentioned features along with an interface to the Unit Under Test are targeted in the project.

The components include serial to parallel command interface, an interface to Unit Under Test, Telemetry Control Signal Generation, Telecommand Processor Data Interface and conversion of data to serial form and vice versa. The package forms an interface between the onboard package and the testing station and sometimes considered as part of test station itself.

**Key Words:** Satellite Subsystem, Automated Testing, Signal Generation, Data Acquisition.

## 1. INTRODUCTION

Satellite System

The satellite is controlled from a ground station through a radio frequency link. The time period for one complete orbital motion of an artificial satellite is equal to the time period of earth's one complete rotation.

Depending on the mission, the link with the ground station may be continuous or can extend over a section of the orbit. Fig.1 shows the view of a satellite system.



Fig 1: View of Satellite System

When the communication between the satellite and the ground station extends only over a section of the orbit, the satellite has to survive for the remaining section of the orbit on its own. For this, it is required to carry out some of the important functions, which play a key role in maintaining the health of the satellite without ground intervention, which is referred to as "Onboard Autonomy" or "Satellite Autonomy".

In the satellite configuration, the Telecommand Processor (TCP) constitutes one separate satellite subsystem with a dedicated microcontroller acting as a client on the system bus. The computer subsystem is also called as embedded system because they serve as the control mechanism for a larger system such as spacecraft command or the telemetry system.

## 2. SATELLITE SUBSYSTEM

### 1.2 Telecommand Subsystem

The Telecommand provides a link between the earth station and the satellite. Telecommand system facilitates uplink for the spacecraft for transmitting command information from the ground station. The command being transmitted is demodulated and decoded by the system to provide the necessary data and signals required for the operation of various subsystems or components in the spacecraft.

### 1.2 Telemetry Subsystem

Telemetry means measuring from a distance. This subsystem provides downlink for the spacecraft. The system accepts data from various subsystems within the spacecraft pertaining the proper functioning of the satellite in either analog or digital form. It multiplexes the input data, digitizes the analog data using ADC. It provides the required modulation for the data stream, which is ready for downlink.

## 3. AUTONOMY FEATURES

Onboard autonomy features of the Telecommand System are as follows:

1. Programmable Automatic Temperature Controller -

For efficient functioning of the system, all temperature sensitive devices need to be maintained in the required temperature range. To meet this condition, pair of

temperature sensors and electrical heater is fixed at required points. Based on the sensor values, Telecommand processor will send control signals to the corresponding heater to maintain the required temperature.

2. Safe Mode -

The safe mode is a part of Fault Detection, Isolation and Recovery (FDIR) implementation. The satellite enters the safe mode if the onboard autonomy detects an anomaly not resolved in real time by redundancy or back up actions. In the safe mode, the satellite basically preserves spacecraft power, thermal survival and communications in the first place until there is ground intervention.

Fault Detection and Isolation recovery logic (Safe mode operation) gets activated with loss of earth presence signal. It generates a safe mode signal to TCP. On reception of the safe mode signals, TCP will execute Safe Mode.

**4. BACKGROUND WORKS**

**4.1 Test Station**

Every component on the onboard package needs to be checked for integrity and accuracy. In order to check the Telecommand package in coordination with the Telemetry package, a test station is designed.

The Test station is a conglomeration of components to identify difference between expected and actual behavior of a process. The Telemetry package is the responsibility of the Telemetry division.

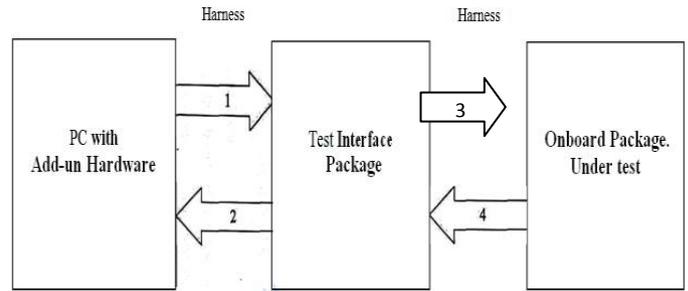
As the Telemetry package is absent at the time of testing, it is simulated using the Test Station

Telecommand test station basically consists of following major parts

- Unit Under Test (UUT)
- Test Harness
- PC based Data Acquisition

The test station simulates and provides all the signals required by the TC system Hardware and monitors all types of outputs by scanning for any spurious operation. The test station is automatic in the sense that a set of commands can be issued and the performance is monitored and verified without operator intervention. The test station also has facility to simulate inputs and monitor outputs stepwise in manual mode for debugging whenever problems are encountered during onboard package testing at various stages.

**5. BLOCK DIAGRAM**



**Fig 2:** Block Diagram of Telecommand Test

**5.1 Design**

The Test Interface Package in the above figure is the Unit Under Test. This is an interface package, which is used to interface the PC with add-on card to the onboard package. The functions of the Unit Under Test are:

- To receive the simulated signals from the PC and to route it to the onboard package after processing with proper interfaces.
- To receive the response from the onboard package and to route it back to the PC after processing with proper interfaces.

**5.2 Software Design**

The software for the test station is designed to operate mainly in two modes. They are

- Manual Mode of commanding
- Sub-system Auto commanding

Manual mode of commanding -

In this mode of testing any command can be issued to TC hardware and the response can be monitored or scanned. If any pulse output is expected for the command the corresponding channel number should be entered.

Sub-system Auto commanding mode -

Any user subsystem such as AOCE, Sensor etc can be selected and a set of their commands will be issued automatically one after another in a predetermined order.

The number of pulse outputs if any for a particular command code is part of the database and will be indicated along with the channel number.

This mode is the most often used mode of testing to check bulk of the TC hardware. Once the sequence is initiated, TC output pulse measurements are made by sending commands and all data from TC package through UUT is acquired and presented as in Manual commanding mode.

### 5.3 FPGA Design

The following functions are incorporated in the FPGA.

- Telemetry Signal generation
- TC Processor Interface
- Command Interface

## 6. STAGES

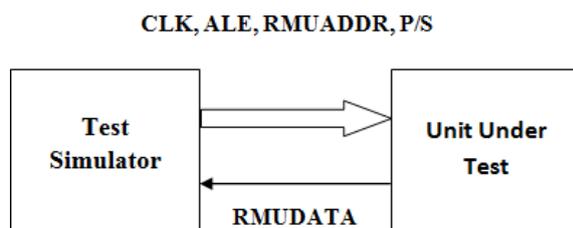
### 6.1 Remote Data Acquisition (STAGE 1)

The Telecommand receives a command from the ground station (Uplink), decodes the command and executes the command to other subsystems.

The Telemetry Control Signal generation is used to calculate the health of the system [2].

Health of the system consists of:

1. Voltage
2. Current
3. Operational Parameters
  - Uplink Register
  - Uplink Counter
  - Execution Register
  - Execution Counter
  - Program Status Word (PSW)



**Fig 3:** Telemetry Control Signals Generation

The signals CLK, ALE, RMUADDR, P/S were generated from test simulator and fed to the unit under test.

CLK –

- This is the clock signal with which the entire FPGA operates.
- It is a 2KHz Signal generated from the 12MHz internal system clock.

ALE –

- This is used to latch the address byte.

- It is a pulse generated in the second half of the eight cycle of the fclk frequency.

- Its falling edge is in synchronization with the falling edge of the P/S signal.

P/S –

- It indicates the completion of converting the parallel data into a serial one at every eighth cycle.

- It is a repetitive signal, which is '0' for 7 cycles and '1' for one fclk cycle.

RMUADDR –

- A free running 8 bit counter (Hex) running from 0 to 255 whose value is shifted serially as per the specified relation.

- This signal carries the serial addresses to Unit Under Test.

RMUDATA –

- An 8 bit data (Hex) (response) from the unit under test is sent or received serially as per the given timing relation

The following is done:

- Generation of Control signals CLK, ALE, RMUADDR, P/S using VHDL language.

- Acquisition and conversion of serial RMUDATA to parallel and storage of the same.

Following are the Input to Test Simulator

- Por – Active high 100 ms
- System Clock – 12 MHz

### 6.2. TC Processor Data (STAGE 2)

Telecommand Processor is used to collect the temperature values of the system, for this Programmable Automatic Temperature Controller is used.

Programmable Automatic Temperature Controller (PATC) is introduced to minimize human dependency and to maintain the satellite surface temperature.

The temperature control for all the components of the spacecraft is by operating the corresponding heaters to maintain within the defined limits. This involves temperature sensing and heater operation. Every heater is associated temperature sensor, depending upon the defined limits of which heater is made ON or OFF limit. If an enable heater's temperature exceeds the upper limit the controller logic will issue 'OFF' command, similarly, if an enabled heater's temperature drops below the lower limit the controller logic will issue 'ON' command.

The Programmable Automatic Temperature Controller can be enabled or disabled and also individual heaters can be enabled or disabled. The temperature upper and lower limits can be programmable depending on the season or ageing [1].

CLK, ALE, FP, MFP, NRZ-L (Health Data)

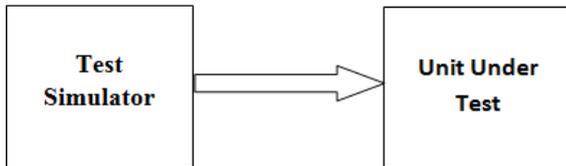


Fig 4: TCP Data Interface Signals Generation

The signals CLK, ALE, FP, MFP and NRZ-L DATA were generated from test simulator and fed to the unit under test.

CLK - Clock - A free running signal with the specified frequency.

ALE - Address Latch Enable - A free running signal with the specified frequency.

- It is used to latch the address and it is high for half clock cycle and low for 8 clock cycles indicating the conversion of serial to parallel data

FP - Frame Pulse -

- A frame is a sequence of 227 bytes of data.
- The Frame Pulse indicates the completion of present frame and start of the new frame.
- Frame Pulse is generated during the transmission of the last byte of the presently transmitted frame.
- This is an active high signal, the ON time being 4ms synchronized with the falling edge of the clock.

MFP - Master Frame Pulse -

- A Master Frame is a sequence of 16 frames, which is nothing but 3632 bytes of data.
- The Master Frame Pulse indicates the completion of the present master frame and the start of new one.
- It is also an 4 ms active high pulse synchronized with the falling edge of clock.

NRZ-L DATA -

- An 8-bit data (HEX) whose value is shifted serially as per the specified relation.
- This signal sends the Non Return to Zero Level (NRZL) - Health data serially.

### 6.3 Command Interface (STAGE 3)

The Telecommand interface is used to send the Telecommand signals to the board package through UUT. The Telecommand signals are of variable length and have to be sent to the onboard package via serial data transmission. A clock signal has to be sent to synchronize data that is transmitted. A window signal is required during active transmission. The Command Interface block describes this component.

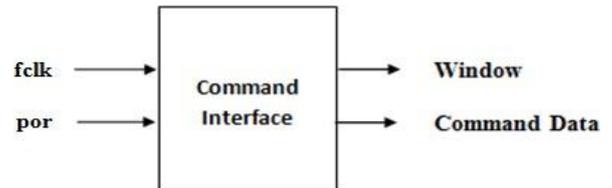


Fig 5: Command Interface

The fclk (1 kHz Output Clock), which is generated from a 12 MHz System clock (Input Clock) is given as a input to the Command Interface and the Outputs are the Squelch (Window Signal) and the Command Data.

The window remains high till the Command Data is transmitted

CMD CLK, CMD DATA, CMD SQUELCH

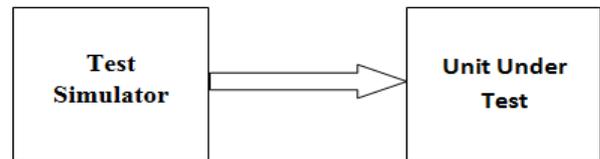


Fig 6: Command Interface Generation

The Command format to the interface will be as explained below:

- The first byte to the interface specifies the command length.
- Following the command length, the number of command bytes (which is equal to the command length) will be issued to the command interface circuit.
- A stop byte will also be sent to it which will be "11100000".

The command interface module will accept these bytes through the internal data bus whenever enabled. Upon receiving the stop byte, the following steps are carried out:

- The module asserts a high on the window pin.
- After 10 clock cycles (fclk), it starts transmitting the complete command serially to the UUT. The window remains high during the transmission. The data bits are transmitted along with the clock signal.

- The window remains high for another 10 clock cycles after the serial transmission is complete.

The signals CMDCLK, CMDDATA, CMD SQUELCH

Were generated from test simulator and fed to the unit under test.

CMD CLK - A burst signal with the specified frequency.

CMD SQUELCH - A burst signal, high during commanding.

CMD DATA -

- Variable length byte wise data, whose value is shifted serially as per the specified relation.
- The length of the data varies from 22 bytes (Min) to 1024 bytes (Max). The data may be stored in a memory and sent serially.

## 7. APPLICATION SOFTWARE

A software application is developed at the front-end to display and store the health parameters that we acquire from the unit under test (UUT). The control signals that are generated using vhdl coding at the back-end are fed into the device which acts as an interface between the PC and UUT. These signals are sent to the unit that we test and checks for abnormalities. Once done, sends a stimulus in response to those signals which here we refer to as the 'Health Parameters' which we can access on the PC via RS232. An application will be developed to access and display the data which is received from Unit Under Test via the FPGA.

## 8. APPLICATION

It can be used in satellite and spacecraft environments. By using advanced technology the same circuit can be expanded to large systems. Minimizes the human intervention and improves system efficiency.

The circuit is designed to work automatically and hence, is simplified and saves time. Almost every testing method can be automated. Furthermore, high- tech design allows for efficient performance.

## 9. ADVANTAGES

- Fast: Runs tests fundamentally quicker than human clients.
- Repeatable: Testers can test how the site or programming responds after rehashed execution of a similar task.
- Reusable: Tests can be re-utilized on various adaptations of the product
- Reliable: Tests perform decisively a similar task each time they are run along these lines disposing of human mistake.

- Comprehensive: Testers can fabricate test suites of tests that cover each element in programming application.

- Programmable: Testers can program modern tests that bring shrouded data.

## 10. RESULTS

Testing becomes easy, accurate and practical with the same sample impossible because of the idea shared above can be implemented in difficulties of accurately measuring the health parameters of the satellite subsystems in future to promote safe construction of the components that go into the making of a satellite. The remote data acquisition, tc processor and command interface stages have been successfully implemented.

## 11. CONCLUSION

As per the presently designed module,

- Telemetry signals were generated as required.
- TC Processor Interface done.
- Command Interface done
- Application Software is developed.

## 12. FUTURE SCOPE

Testing is an inevitable process and this project focuses towards forecasting testing for existing and future satellite systems. The project has enormous potential for further enhanced testing of future satellite systems as their basic configuration remains more or less the same. The developed test system is automated and thereby reduces human interference to the maximum limit. This project can be further extended to test aspects of satellite subsystems that are not dealt with in this.

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