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Design of Telemetry in Student Imaging Satellite

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ABSTRACT: PES Institute of Technology along with five other institutions is developing a student imaging satellite. This satellite is planned to be launched in around 650 km polar sun synchronous orbit at an angle of 99°. This project serves as a platform for students to understand and deal with the advanced space technologies. This paper reports the entire telemetry process in student imaging satellite i.e., acquiring data from various sources and mapping, creation of master telemetry frame and transmitting master telemetry frame to ground. The transmitted telemetry frame gives the entire information about what is happening on the satellite or spacecraft. Typical telemetry frame presented in this paper.

Keywords: Data Acquisition and Mapping, Telemetry, On Board Computer, Student Imaging Satellite

I. INTRODUCTION

Student imaging satellite project main objective is to benefit the students in order to increase their knowledge and skills to deal with the working of satellite [1]. Students will develop an understanding of the decisions that a scientist makes when designing a satellite. The imaging satellite which we are building will capture clear picture of the earth. Using this picture we can estimate various conditions of the earth. This satellite will be launched in a polar sun synchronous orbit at an altitude of around 650 km, inclined at an angle of 99° to the equator. The orbital period is around 90 minutes. [2] The micro-controller used is Atmel's AT32UC3A0512 processor, which is 32 bit, 512Kb processor. AVR studio software and embedded 'C' programming language are used for programming. Main hardware components are Magnetic Torquer (Actuators), Magnetometer, power sensors, sun sensors, Thermistor, Rx, Tx, camera and solar panels [1]. The principal objective of satellite telemetry is to provide mission data as well as information for operational use and failure analysis, and to predict spacecraft performance. Telemetry design is the main approach used in student imaging satellite to know about the status and health conditions of the spacecraft. Telemetry is the data or information which is sent from spacecraft to ground station. In case of failures or anomalies, the telemetry data helps to determine the causes, events and means to ease or work against the problems set forth by a failure. Telemetry can also be used to predict and analyze any degradation or deterioration that might negatively affect performance and hence decrease spacecraft lifetime.

The parameters involving the satellite health condition must be known to the ground stations at all times in the entire mission. These parameters include power, currents, temperatures, altitude and the battery voltage etc... These parameters hold information about spacecraft resources, health, attitude, spacecraft orbit and timing data for ground navigation. In the telemetry process, different types of data from various sources are acquired from the sensors. The acquired data has to be mapped and form the telemetry frame format. Telemetry frame format contains 223 bytes and each frame contains word of size 32bits. These frames will hold the parameters and sends to the ground station. The flow how this process works is clearly explained in the telemetry design section.

This paper is structured as follows: section II describes On Board Computer Software which briefs the software architecture and software system. Section III describes the telemetry design. Section IV describes sequence diagram of telemetry design. V concludes the paper with further enhancements.

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II. OBC SOFTWARE ARCHITECTURE

In this section, we describe the OBC system architecture.

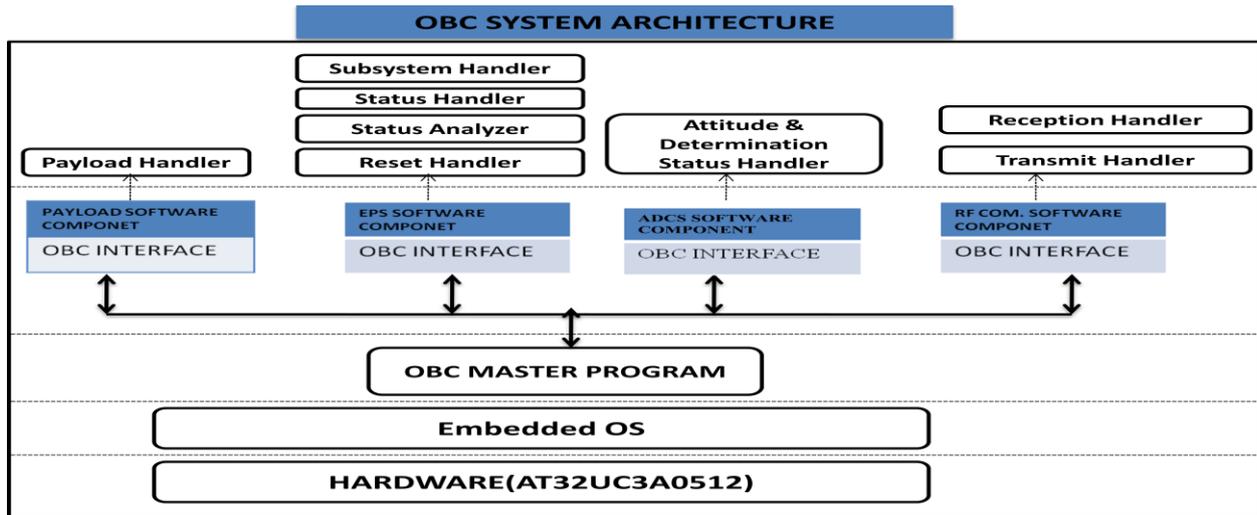


Fig: 1. OBC Software Architecture

Figure 1 explains the functionalities of each component in the OBC system software. Camera or Payload's will capture the image and it does the possible compression required and stores it in telemetry [3][4]. Power systems will handle the power supply among various components. ADCS's will control the attitude and orientation of spacecraft. Telemetry (Tx) is used for transmission of data to ground station after forming a frame that includes both housekeeping and payload data. Log's used to obtain the data from various components and stores in a specific address of memory, and Tele command's function is to accept the data or commands from ground which will get executed in spacecraft.

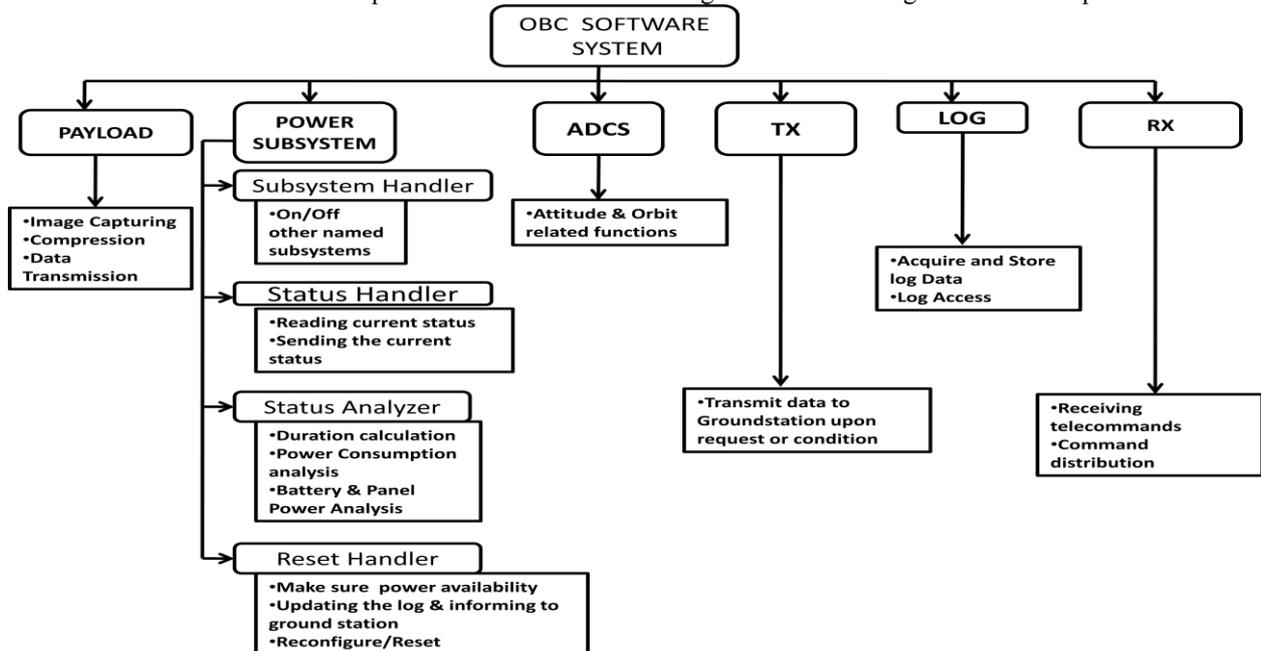


Fig: 2. OBC System software

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III. TELEMETRY DESIGN

We are using the component based development cycle to develop the OBC components. The main purpose of using this component based development cycle is to develop and test each component independently. Once all the components are developed independently, we integrate them with less overhead. In the student imaging satellite, the software will contain many components, where each component has its own functionalities and capable of doing particular tasks. The components involved are : system main program, power on initialization, common subroutines, analog data acquisition, digital data acquisition, magnetometer data processing, on-board timer processing, de-tumbling mode, SRC, SAOC, suspended mode, actuator processing, tele commanding, telemetry, remote programming.

Telemetry is the process of collecting the data using automated sensors. These sensors collect different types of data and form the telemetry frame. The quantities sensed from the sensors are the parameters to telemetry frame. The formatted frame will be transferred to the ground station. Figure 3 shows the telemetry processing picture.

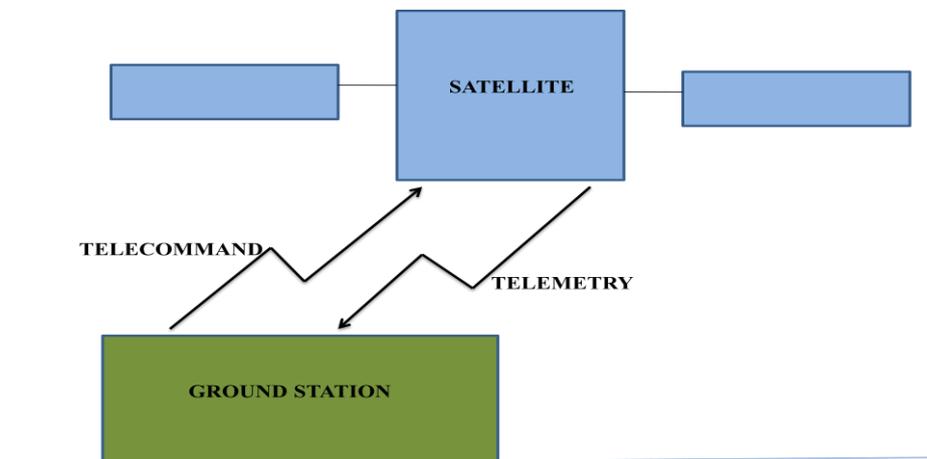


Fig. 3 Telemetry Processing

Types of telemetry data include: analog data from analog data acquisition process, digital data from digital data acquisition process, ADCS data which is a processed data from ADCS operations, and tele command related data.

TELEMETRY PROCESS INVOLVES 3 COMPONENTS

- i. Telemetry Data Acquisition and Mapping
- ii. Creation of the formatted TM frame
- iii. Serial transfer of data to Telemetry port

In the telemetry data acquisition, data from various sources are acquired. Analog data include data from sun sensors having 6 channels, thermistor having 5 channels and power sensors having 10 channels. The collected data from these sensors are acquired in analog data acquisition process. Digital data include command counter, command, one bit status of the components and event flags. All these data are acquired in the digital data acquisition process. Raw data buffer from data acquisition module, processed data from ADCS module are acquired and the OBC processor logic stores the acquired telemetry data in telemetry RAM.

Figure 4 shows the realization of normal telemetry process. The collected data from sensors will be stored in the data acquisition buffer. Then mapping has to be done from data acquisition buffer to telemetry buffer. Number 1 to N in the below figure represents the number of words in telemetry buffer along with the index table reference value. With this acquired data, telemetry frame can be created. The data from formatted frame will be transferred to the telemetry port. The whole process is clearly showed in the below figure.

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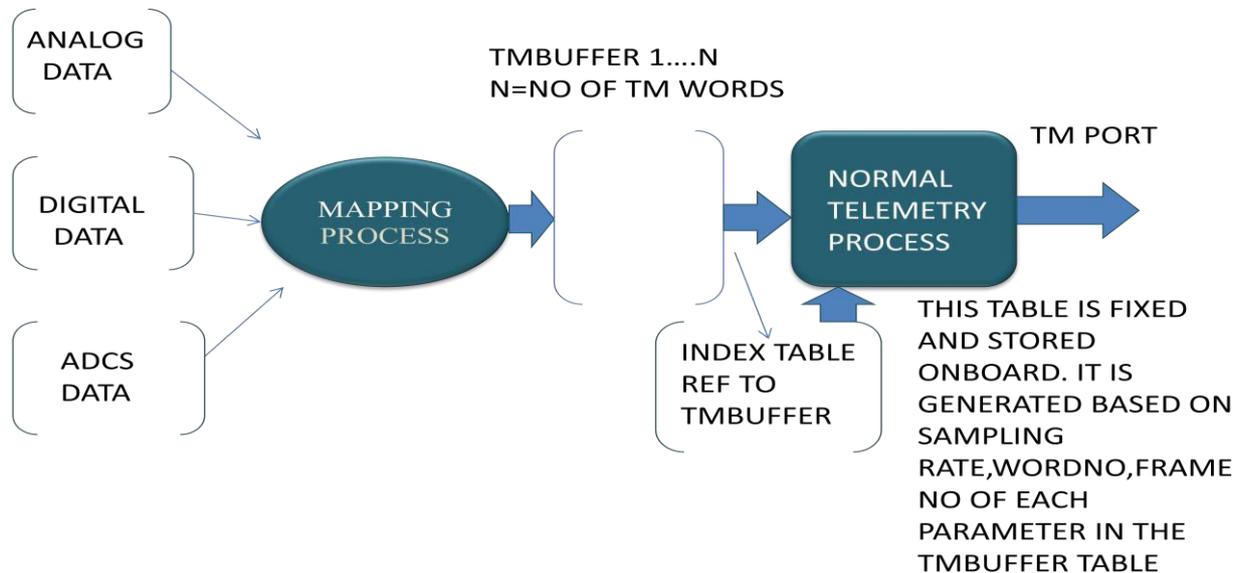


Fig: 4. Realization of Normal Telemetry

Figure 5 shows the overview of mapping of data from Data acquisition buffer to Telemetry buffer RAM and dumping data from Telemetry buffer RAM to TM Frame. The brief introduction about the internal process of the mapping and dumping of data follows like this, first get the address of data acquisition buffer, telemetry buffer1, telemetry buffer2 and telemetry port. Read the data from data acquisition buffer and store it in TMRAM buffer. Now read the data from TMRAM buffer and format the TM Frame each of size 223 bytes. Read each frame one by one and dump into the Telemetry port.

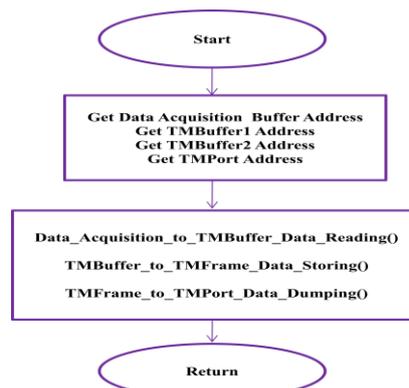


Figure: 5. Overview of mapping of data from Data acquisition buffer to Telemetry buffer RAM and dumping data from Telemetry buffer RAM to TM Frame.

Figure 6 shows the overview of mapping of data from Data acquisition buffer to Telemetry buffer RAM, and also reading data from TMRAM buffer and formatting TM Frame containing word each of size 32 bit.

We use two flags here, `TM_Buffer1_flag` and `TM_Buffer2_flag` for telemetry buffer1 and telemetry buffer2 respectively. Read both the flags and evaluate the `TM_Buffer1_flag`, if the output of evaluation is 00 it indicates that Buffer1 is empty and start filling that buffer. Now simultaneously start to read the data from TMRAM buffer1 and format the TM Frame each of size 223 bytes. Set `TM_Buffer1_flag` to 10 which indicate the buffer1 is filling. Once the buffer1 is full, set `TM_Buffer1_flag` to 01 which indicates that the buffer is full. Now evaluate `TM_Buffer2_flag`, and perform the same procedure as followed in `TM_Buffer1_flag`. Once buffer is full, set `TM_Buffer2_flag` to 01 to indicate the buffer2 is full.

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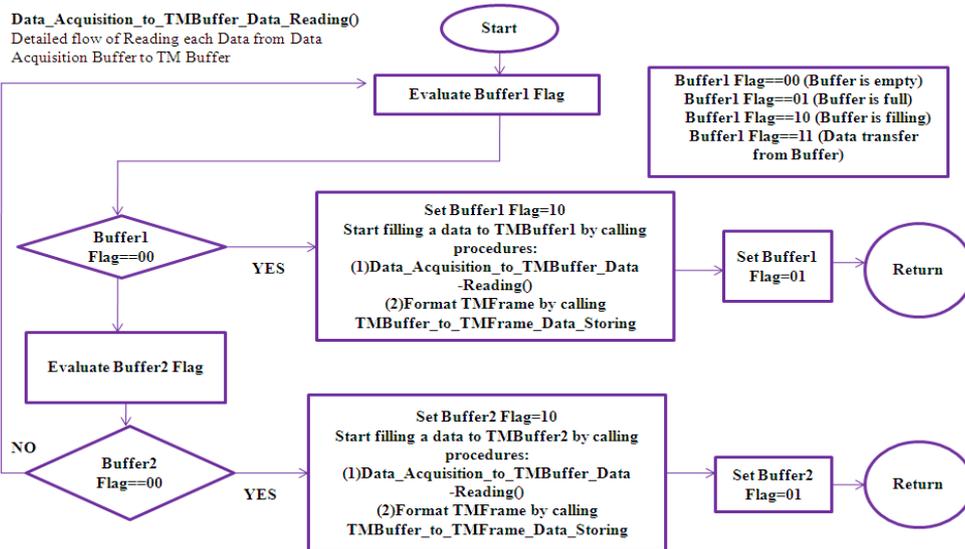


Fig. 6. Overview of mapping of data from Data acquisition buffer to Telemetry buffer RAM and read each data from Telemetry buffer make it as TM Frame word of 32 bit and store it in TM Frame.

Figure 7 below explains the overview of reading TM Frame from Telemetry buffer RAM and dumping into the Telemetry port. Initially read both TM_Buffer1 and TM_Buffer2 flags and evaluate the TM_Buffer1_flag. If it is 01, indicates that the Buffer1 is full and start reading TM Frame and dump into the Telemetry port. Set TM_Buffer1_flag to 11 which indicate that the data is transferring from buffer1. Once the buffer1 is empty, set TM_Buffer1_flag to 00 indicating that the buffer1 is empty. In the same way evaluate the TM_Buffer2_flag.

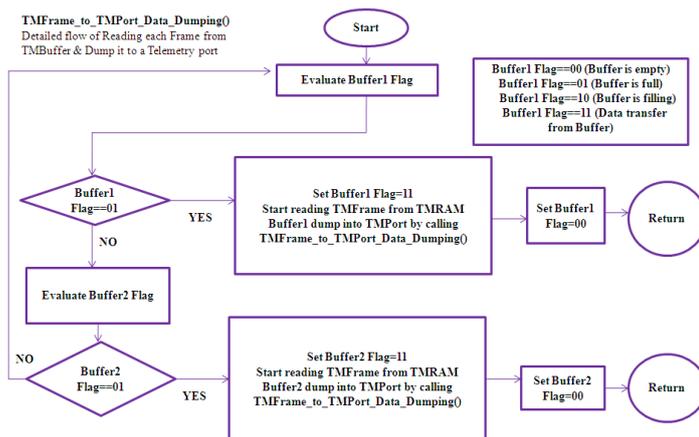


Fig 7. Overview of reading each TMFrame from TMRAM buffer and dump into the Telemetry port

IV. SEQUENCE DIAGRAM

Figure 8 shows the sequence diagram for mapping of data from Data acquisition buffer to Telemetry buffer RAM and dumping formatted frame to the telemetry port. This sequence diagram helps to examine all the steps explained in the telemetry section.

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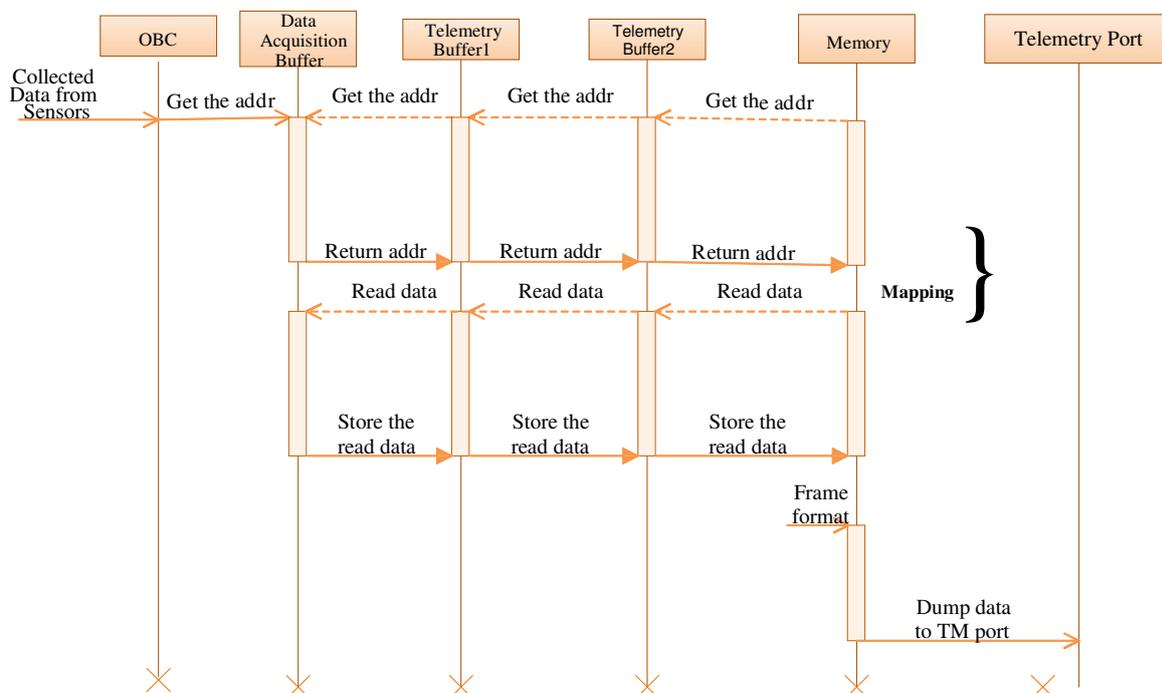


Figure: 8. Sequence Diagram of mapping of data from Data acquisition buffer and dumping data from Telemetry buffer RAM to Telemetry port

V. CONCLUSION AND FUTURE WORK

The student imaging satellite, helps to understand and gain knowledge about the satellite. This paper is of telemetry processing which deals with the working of telemetry i.e., how the telemetry acquires the information from spacecraft and process that information. The future plan which we can carry out to this is, implementation and simulation of telemetry in reality.

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Dr V. K Agrawal has obtained his Bachelor of Engineering from Jiwaji University, Master of Technology from Indian Institute of Technology, Kanpur and Ph.D, from Indian Institute of Science, Bangalore. He has worked as LGM, Electrical and S/W Architecture, General Motors R &D India Sc Lab and ISAC ISRO as ISRO Group Director, Control Systems Group. Now he is with the PES Institute of Technology, Professor in ISE & Director in CORI. He has received Sir C.V. Raman Award, Astronautical Society of India Award, Govt. of India, Dept of Space Merit Award and 18th IETE- Hari Ramji Toshniwal Gold Medal Award. He has published more than 120 research papers in many international journals and conferences. His research interest areas are small satellites, software engineering, reconfigurable computing, embedded systems, cloud computing and control systems etc.