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TSAT Student Flight Processor and Ground Support Equipment

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Abstract

The Taylor Satellite (TSAT) will utilize a student flight processor for on-board data acquisition and transmission. The data will be packaged in an array that is sent to the main flight processor, and finally arrives to the ground support equipment (GSE) station. Two types of processors are scheduled for flight. The first of these, the PIC18F2620, is a tried and tested processor that has been used in multiple Taylor University balloon and satellite projects and launches. The second, the cutting-edge Actel Fusion Field-Programmable Gate Array (FPGA), is a brand new chip featuring low power and robust computing capabilities. Although the Actel Fusion is flight-certified, it has never been flown in space. The TSAT project will be the first satellite to fly the Fusion, which will be flown in conjunction with the 18F2620. The main data sets will be secured through the 18F2620, while the FPGA will simply output a standard square wave pulse to check the flight-readiness of the new Fusion chip. The design and implementation of the GSE software is for the reception and retrieval of data from various student and faculty developed sensors on board the TSAT. The innovation of the GSE is its ability to utilize the Iridium network of satellites during the inflight stage of TSAT for all data acquisition. The Iridium satellite constellation is a large group of satellites providing voice and data coverage to satellite phones, pagers and integrated transceivers throughout the Earth. This subsystem also involves building GSE hardware to control the power supplied to the sensor and microcontroller during the testing phase of its development, with the 34972A LXI Data Acquisition / Data Logger Switch Unit as its driving instrument. The hardware system will also capture important data from each sensor such as voltage and current draws as well as a current draw from the entire student bay.

Introduction

The Taylor Satellite (TSAT) is a dual cube satellite launching under the NASA ELaNa program on the CRS-3 Space-X flight from Cape Canaveral to the International Space Station (ISS) as scheduled in the summer of 2013. The operating altitude of TSAT is at an extremely low earth orbit (ELEO) with a release height of 325 km above the Earth. TSAT includes five sensor systems: a thermal array, a UV sensor block, an E-field/VLF sensor capsule, an electron density plasma probe, and a solid state particle detector (SSD)[6]. In order to transmit data to the ground support equipment (GSE), TSAT is equipped with an ISS ham radio relay link and a modem approved for connection to the global Iridium satellite network.

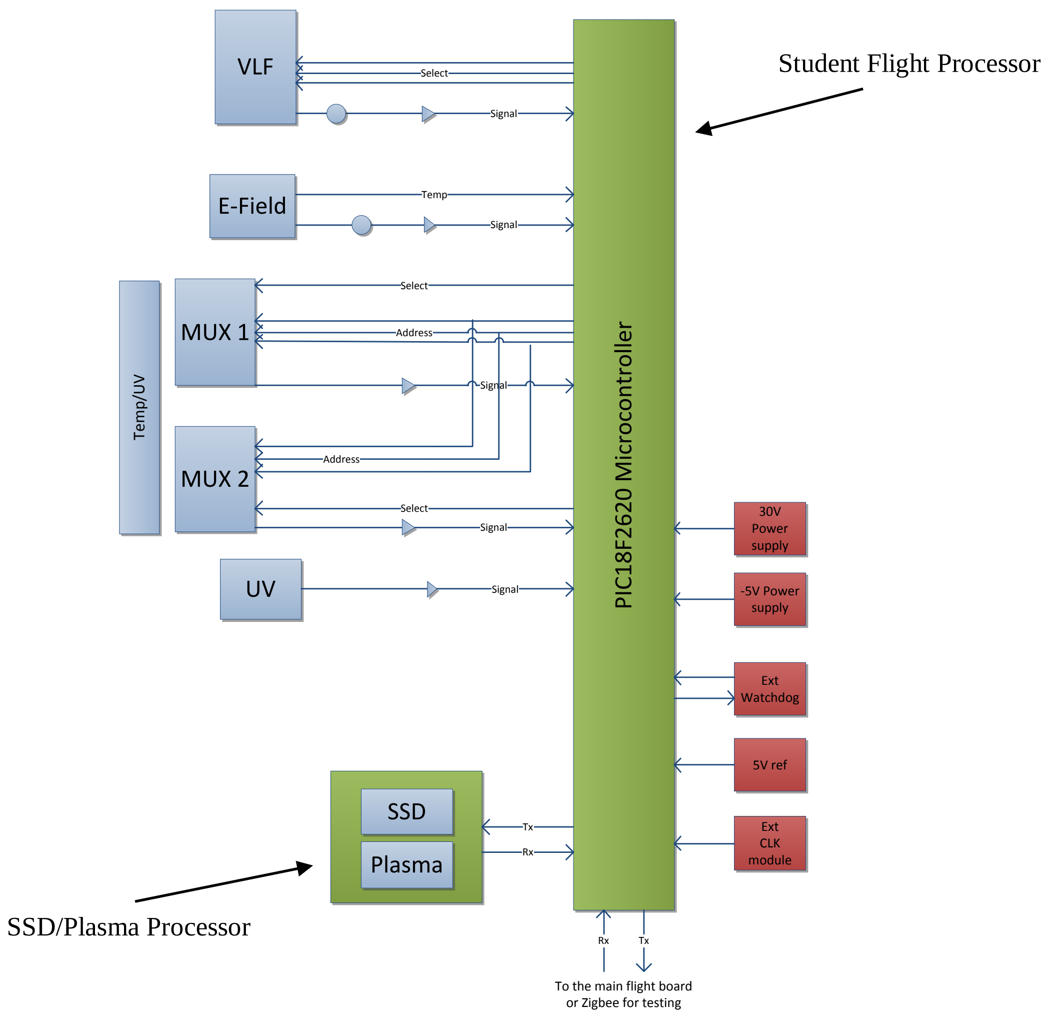

Figure 1: Student Flight Board Diagram

Sensor analog data is collected by two student-developed PIC18F2620 processors before being serially transmitted to a flight control processor. One design objective is to provide a robust interface between the two student processors with an adequate number of I/O pins to collect sensor data and to recalibrate certain sensors. As shown in Figure 1, the thermal, UV, and E-field/VLF data is sampled by the student flight processor while the SSD/Plasma processor samples the plasma and SSD data separately. The latter transmits its data serially to the student flight processor which, in turn, stores the data from the instrument bay until it is polled by the main flight control processor.

Flight and Testing Hardware

The GSE testing hardware for TSAT is designed for both power supply and regulation during the testing phase. The system provides power to all subsystems aboard TSAT while regulating the current draw from each component. The GSE testing hardware is implemented by using an Agilent® 34972A Data Acquisition Unit and a C++ program for all the controlling software. This system is to be replicated on the flight board during launch for testing purpose.

The TSAT student flight board hardware consists of a PIC18F2620 processor and an Actel Fusion® AF090 FPGA to integrate the various hardware components interacting with each other. The 18F2620 is a tried and tested processor to be used as the primary component for acquiring data and performing computations. Though the flight-certified AF090 processor has never been flown before, one of the goals of the TSAT mission is to test the design functionality of the chip while in space.

The student flight processor board consists of three major components: the PIC18F2620 and AF090 FPGA processors, and the interfacing hardware. As mentioned previously, the PIC18F2620 has flight heritage, serving in multiple Taylor balloon flights and experiments. It includes a built-in 10-bit ADC, which is the ADC used for the TSAT flight. The 18F2620 has an internal 4MHz clock, but the TSAT flight uses a 20MHz high speed external clock to maintain its timing scheme. The processor has 28 pins, where 10 of its input channels are a part of the 10-bit analog-to-digital (A/D) module. Eight of these channels are used as analog inputs for the TSAT flight.

Table 1: Flight Processor Specifications

Performance Specifications	
A/D Converter	10-bit
Clock	High speed external clock, 20 MHz
Power Supply	+30 V and ±5 V
Serial Comm	TTL
Baud Rate	38.4 kBd
Memory	3968 bytes SRAM
	1024 bytes EEPROM
I/O Ports	3 Ports (A, B, C)
Physical Specifications	
Max Power	1.0 W
Mass	50 g
Size	Fits in 3"x3" board
Voltage Requirement	+5 V

The interfacing hardware allows for communication between the student flight processor and the main flight control board together with the additional data acquisition processor and the flight sensor board. The interfacing hardware ensures that the input signals from the sensors are filtered and processed appropriately to ensure that the controller operates under its safety and functionality parameters.

Field-Programmable Gate Arrays are powerful chips that are reprogrammed to model a variety of different processors by reconfiguring the gate hardware. Flying the AF090 tests the durability of the hardware in a space environment. The AF090 outputs a simple, periodic pulse to ensure that the hardware functionality of the chip.

The Agilent® 34972A Data Acquisition Unit is a 3-slot mainframe with a built-in 6 ½ digit DMM and 8 different switch and control modules. For the GSE testing hardware, three different modules are used as Figure 2 illustrates GSE Testing Hardware. The 34902A module is used to measure voltages across sense resistors to determine the current draw from each subsystem.

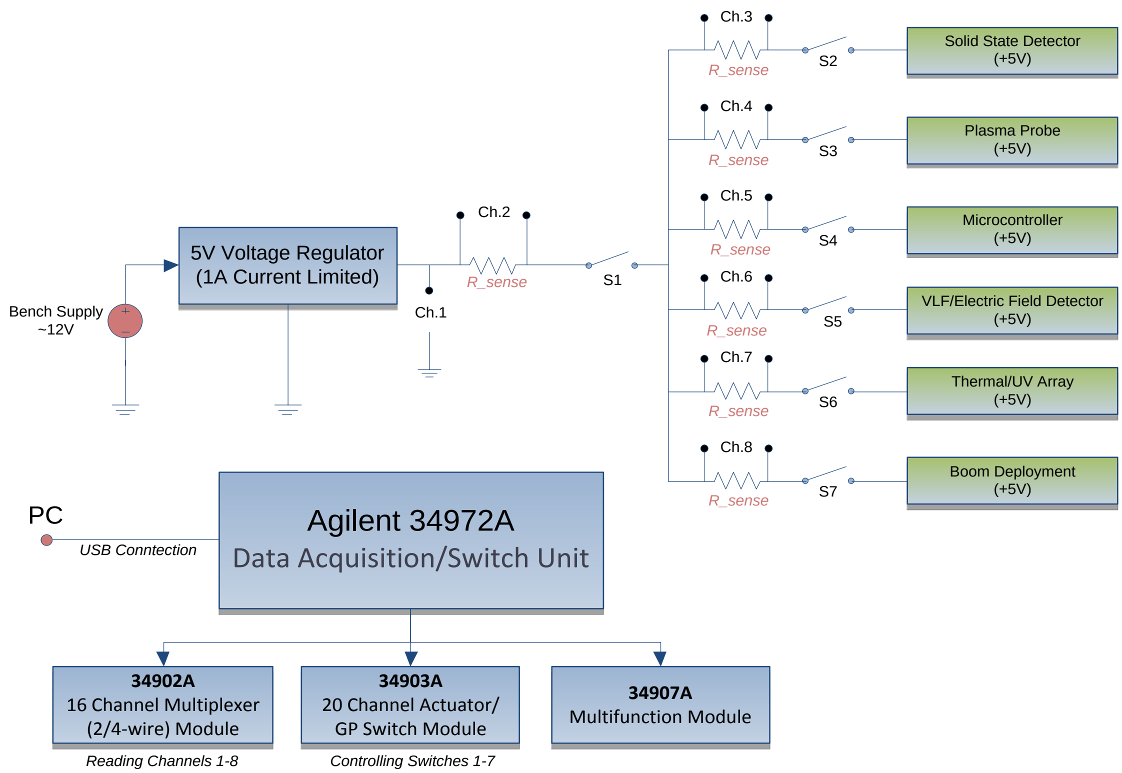

Figure 2: GSE Testing Hardware - Agilent®

The 34903A module is used to control all operations of switching with the ability to turn on and off each individual subsystem as well as that of the entire satellite. Further the module provides a control to power down any subsystem automatically that surpasses the maximum power consumption allowable. The 34907A module is used to read digital inputs as well as providing two 12 volt, analog outputs for any necessary voltage references. The test bench for this system consists of a printed circuit board (PCB) on which the Agilent® system connects to a 48-pin connector that is centrally located and serves to relay all outputs and power lines for the various subsystems.

Data Acquisition

The student flight processor collects all of the satellite sensor data for transmission to the main flight control, and serves to filter this information for proper accuracy. The student flight processor runs in two different modes: a high speed sampling mode and a low speed sampling mode. The low speed sampling mode is used in the upper bound of the flight, between 100 and 300 km into the atmosphere. At an altitude of around 100 km, the satellite is expected to make a quicker descent through the atmosphere, necessitating therefore a higher operating speed for acquiring the data that is being encountered. At lower speeds (i.e. higher altitudes of flight), each of the sensor sample rates are designed to collect data every second; similarly, the Plasma/SSD processor is polled every second. In contrast, for higher flight speeds (i.e. lower altitudes), the Plasma/SSC processor is designed for polling at 100 times per second and the E-field sensor at a 1000 times per second; all other sensor data, however, are anticipated to be sufficient at the one sample per second rate. During the high speed mode, the E-field and Plasma/SSD data is averaged in order to provide representative data while constraining the amount of transmitted data to a reasonable size. Figure 3 displays the software structure flowchart for the student flight processor that toggles between the two sample modes.

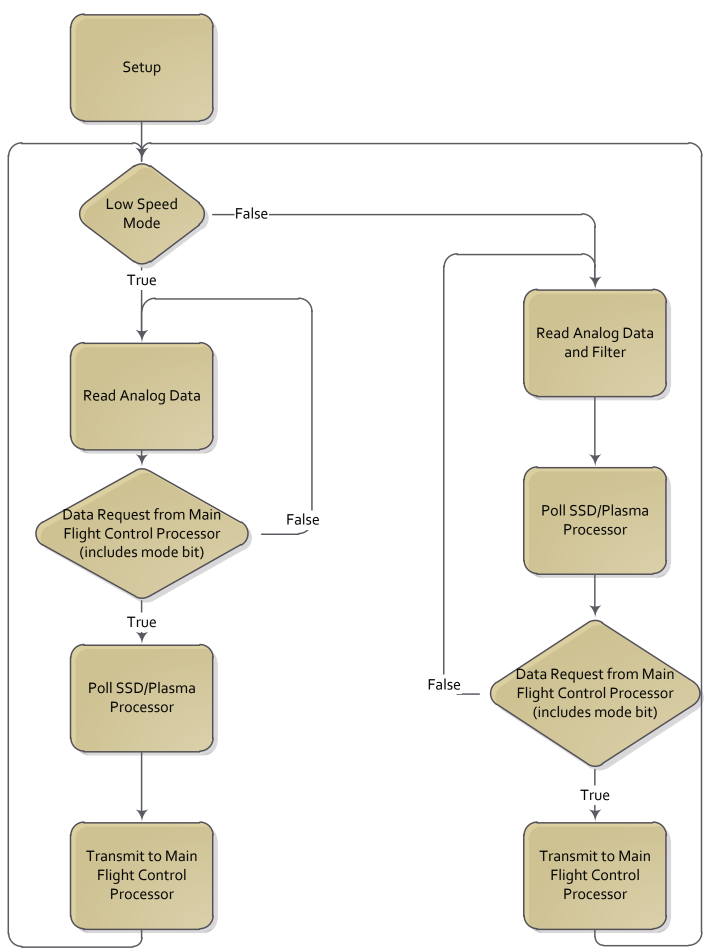

Figure 3: Student Flight Processer Software Flowchart

Data Telemetry

During the ground testing phase of development, the input for the GSE software is transmitted via ZigBee radio from the Flight Board. This is implemented by using an XBee® radio for wireless transmission. Data is packaged in a similar manner as with the Iridium transmissions resulting in GSE software that is more amenable for collecting and manipulating such information. Iridium provides Short Burst Data (SBD) in 286-byte packages as an e-mail attachment. SBD is used for a simple while effective network transport process for transmitting short data messages. While TSAT is in flight, the input comes from both the Iridium network servers and a Taylor server maintaining beacon via the internet.

Data Manipulation – GSE Software

All sensor outputs are processed, parsed, and stored in a database. A program utilizing MATLAB® then pulls data from this database and displays said data on various charts and graphs. In that same program, there is a main dashboard containing flight health information such as voltages, currents, and pressures along with more detailed displays for the individual sensors.

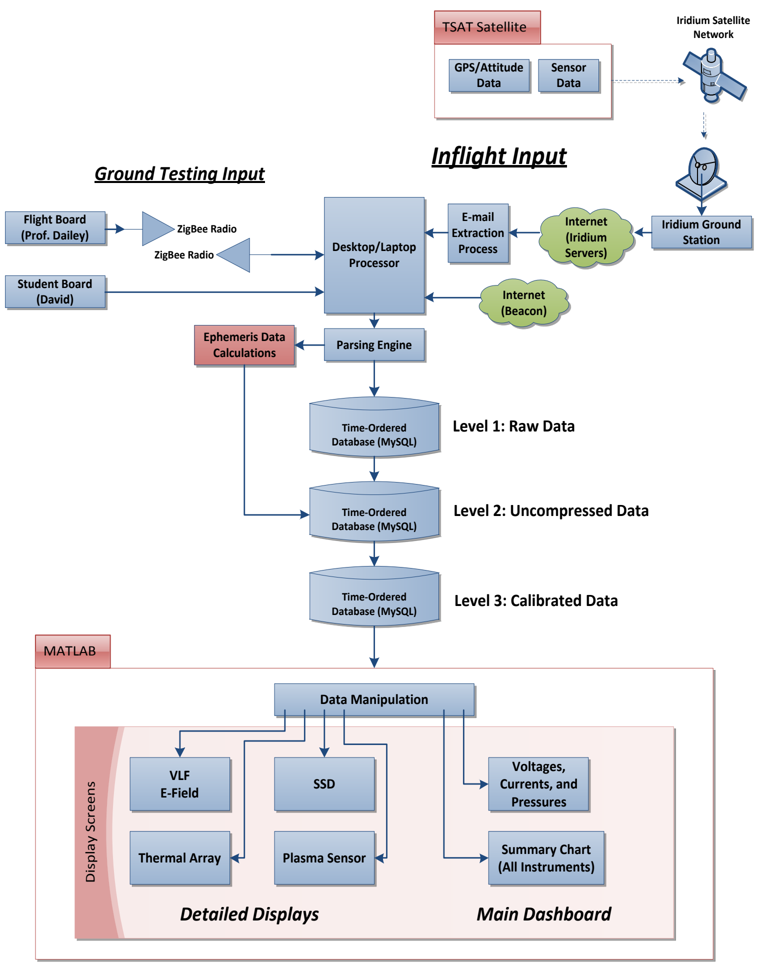

Figure 4: GSE Software Diagram

The software is implemented through a C++ program and used for controlling the GSE testing hardware, handle data parsing/storage, and interface with MATLAB® tools for data dashboards. Figure 4: GSE Software Diagram illustrates how the software handles data acquisition, storage, and display. While the satellite is in flight, data is extracted from Iridium SDB and parsed to be stored in a database. The database itself is ordering the time-stamped data as well as dividing it into three separate levels[2]. The calibrated flight data is then pulled from the database and manipulated using MATLAB® and displayed on individual diagrams and tables.

Conclusion

Together, the student flight processor and the GSE will manage the data acquisition and telemetry systems in order to accomplish TSAT's mission. Developing the student embedded processor and ground support equipment serves the dual purpose of furthering satellite research and educational learning objectives. Working with a diverse team on a project with real costs, deadlines, requirements, and a real launch with NASA is an invaluable experience to students on the present research mission, and to future students of related learning endeavors.

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