Simplified Scheme for Data Acquisition in Student Imaging Satellite

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Abstract: PES Institute of Technology and SKR College of Engineering along with four other institutions are developing a student imaging satellite. The project serves for students as a platform for understanding and dealing with advanced space technologies. This satellite is planned for launching in around 650 km polar sun synchronous orbit at an angle of 99º. The satellite functions are controlled by centralized computers called On- Board Computer (OBC). This OBC software which is developed on ATMEL processor performs all the computational tasks of the satellite. The Development methodology for OBC software used here is component- based. This paper reports the simplified design for acquisition of both analog and digital data in the satellite. Both the analog and digital data acquisition are implemented as independent components and as an integral part of OBC software. These acquired data are necessary to manage satellite's housekeeping and control functions.

Index Terms: Analog Data, Digital Data, On Board Computer, Student Imaging Satellite;

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I. INTRODUCTION

PES Institute of Technology and SKR College of Engineering along with four other institutions are developing a student imaging satellite. The main objective of this Satellite is to excite students in space technologies. It is a spin stabilized imaging satellite which is designed to capture the pictures of the Earth. This satellite is planned to be launched in a polar sun synchronous orbit at an altitude of around 650 km, inclined at an angle of 99^o with an orbital period of around 90 minutes. The overall functionality of this student imaging satellite is controlled by its centralized software. The micro-controller used in the OBC is ATMEL AT32UC3A0512 processor [1] which is a 32 bit 512Kb processor. Development Software used is AVR studio and the programming is done in embedded 'C' language. The main hardware components of the satellite include Magnetic Torquers (Actuators), Magnetometer, power sensors, sun sensors, Thermistors, Receiver, Transmitter, camera and solar panels. These components and its interfaces with the on-board computer (OBC) are pictorially depicted in figure 1. Camera used here is NANOCAM C1U (CMOS, 2048 X 1536) which is connected through I2C interface. Magnetometer used is HMR 3400 with RS232 interface. Heaters and torque roads are connected through drivers. Analog components include 4п sun sensors, power sensors and temperature sensors. These are connected among microcontroller's analog channels and 16:1 multiplexer input lines. Receiver, Transmitter baseband functions are realized in FPGA and suitably interface with the OBC.

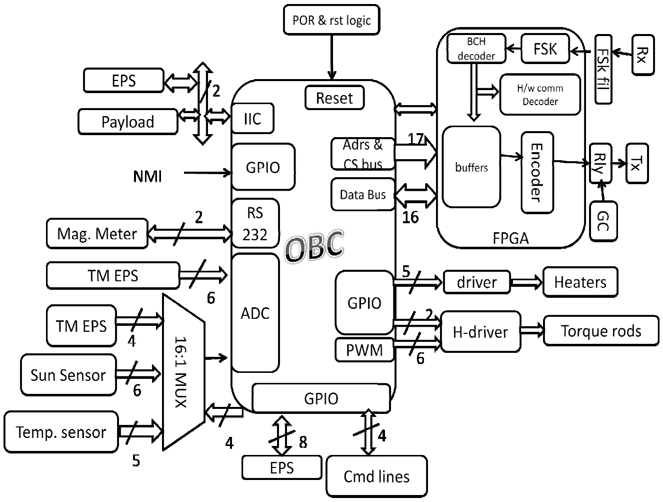

Fig 1: OBC Hardware Architecture

Data acquisition is a technique adopted for acquiring and storing of the data. One can easily speculate in any system that, acquiring data from one component and making that data available for other components is the most basic need. This process is also the means of interaction between components. In this satellite we have divided the data acquisition process into two parts, namely, analog and digital. Analog data would include data from sensors whereas the digital data include data from the ports and the registers.

This paper is structured as follows: Section II describes the On- Board Computer Software which provides a brief description about the OBC software architecture and OBC component diagram. The simplified scheme for analog and digital data acquisition is pictorially discussed in section

III. Finally, the paper is concluded with future enhancements in section IV.

II. ON- BOARD COMPUTER SOFTWARE

The high level architecture of OBC software embedded in its micro-controller AT32UC3A0512 is portrayed in figure 2. The OBC master program which is implemented above the embedded OS acts as an intermediary between Hardware components and the micro-controller. Its main task is to collect the inputs from the respective components and to provide the computed result as the output to the appropriate components. This software is mainly divided into Payload- related, EPS (Electronic Power Supply) -related, ACS (Attitude control system)- related and Receiver (Rx) and Transmitter (Tx)- related.

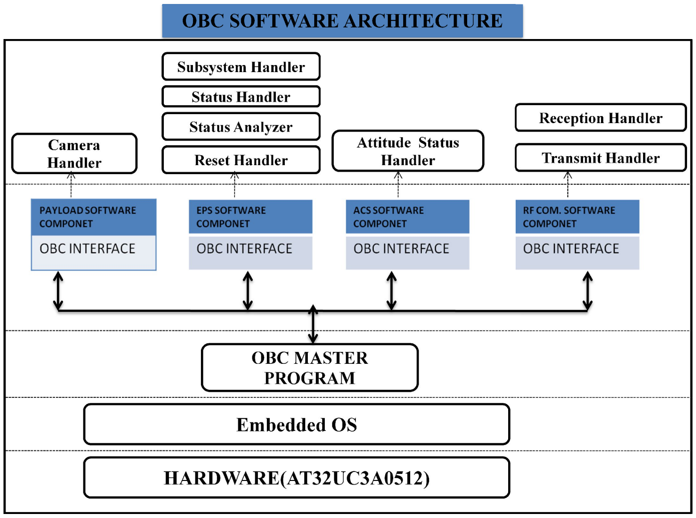

Fig 2: OBC software Architecture

In this software, the function of the camera is to capture the images, do possible compression and store it in the telemetry. ACS controls the spin and the attitude of spacecraft. Telemetry (Tx) is about forming a frame that includes housekeeping and transmitting the frame to ground station. Log's functionality is to acquire the data from various components and storing in specific address in memory. Telecommands duty is to receive the data or commands from ground which will get executed in spacecraft. Power system is responsible for managing the power among various components.

The figure 3 provides a pictorial representation of the component diagram for OBC software. Here, Real Time Executive (RTE) is the main program which is divided into 4 minor cycles each lasting for about 16 milliseconds. Thus 64 milliseconds are taken to complete one full cycle which is one major cycle. All the sub- programs store the processed data at a particular address in memory. After this, the telemetry takes the starting address and number of words of each kind of data, maps that data on to a frame and then transmits the frame to the ground. This frame is the only means of knowing the happenings a in satellite.

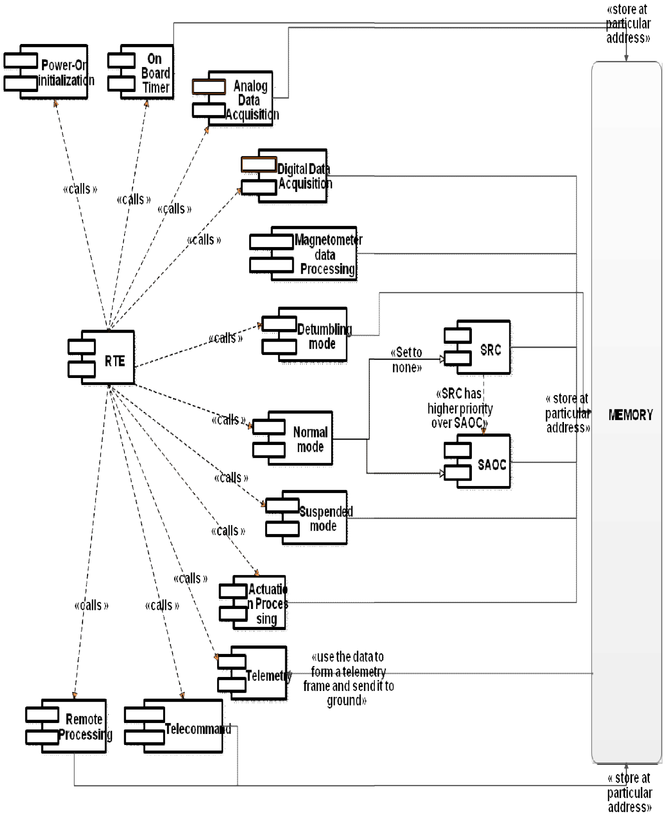

Fig 3: Component Diagram for OBC

III. SIMPLIFIED SCHEME FOR DATA ACQUISITION

Data acquisition normally implicates combined acquisition of analog and digital data. But in our case it includes independent acquisition of Analog and digital data. Hence they are implemented individually. One advantage of this is that, these individual components can be reused with fewer modifications. Acquired data are transmitted down to ground station which is necessary to monitoring system for housekeeping purposes. This section is presented with the simplified scheme for analog and digital acquisition.

Usually in typical OBC, data acquisition was done without distinction between analog and digital data. Though this particular approach was straight forward for development, it was very cumbersome for searching particular data within a short period of time. This overhead is more severe in satellites with short orbital period since they are in line of sight for very little time. The purpose of dividing the data acquisition into analog and digital are mainly for flexibility and independency.

The development methodology used here is a component- based development cycle. This model helps us to develop and test each component independently [4]. This flexibility leads to better interfacing with other components. Once all the components are developed individually, they are integrated with less overhead. Thus, this model provides some sort of abstraction while building and ensures that the individual component will remain unaffected on merging with other components. The processor we are using is UT32UC3A0512 which is 32- bit, 512 Kb micro-controllers with a speed of 1.49 DMIPS (Dhrystone MIPS)/MHz which is adequate enough for our mission. Visual Studio software is used to program the ATMEL processors. It has libraries which contain in-built functions through which we were able to configure and communicate by passing parameters to those functions. Programming language used here is Embedded C. The software data acquisition is divided into following components: i) Analog data acquisition and ii) Digital data acquisition.

Figure 4 and figure 5 provide the architecture of data acquisition and interaction of ADA and DDA respectively. During data acquisition, supervisor software calls ADA and DDA one after the other sequentially. Among the acquired data, sun sensor's data and component's status data are used in de-tumbling mode. SRC and SAC which are used to actuate magnetic Torquers as and when needed depend upon sun's position and other attributes. Tele-command and telemetry use event flag information collected by DDA to decide when to receive or send data correspondingly. Power sensor data and component's status data are used to switch the components between on and off according to power requirements. Temperature sensor's data are used to switch heaters between on or off in order to keep the overall temperature within acceptable ranges.

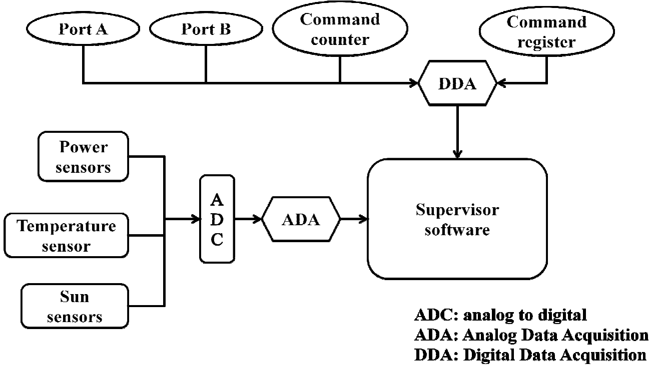

Fig 4: Architecture of Analog and Digital Data acquisition

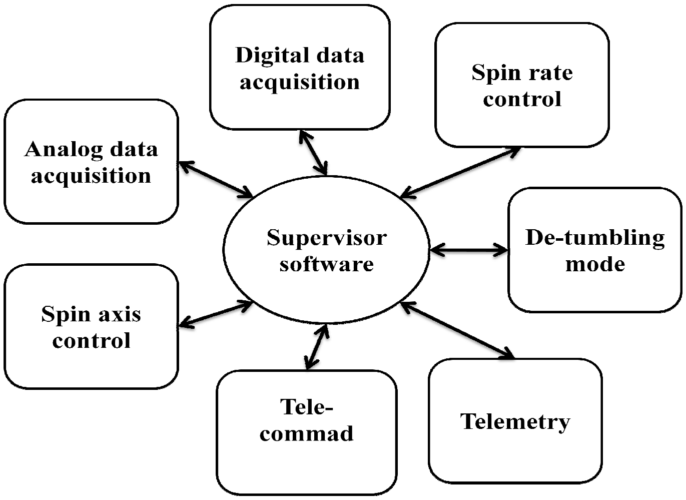

Fig 5: Interaction of ADA and DDA with other components

Below section describes the analog and digital data acquisition in detail.

Analog: In our mission, analog data include data from Sun sensors (6 No s), Thermistors (5 No s) and Power sensors (10 No s). The micro-controller used here has only 8 analog channels but it is clearly seen that the requirements extend to 21. Hence we appended a 16:1 multiplexer to our micro-controller, after which the total count of our analog channels now goes to 7+16 i.e., 23, which will satisfy our requirements. The hardware design of this analog data acquisition is rendered in figure 6. Among 10 power sensors ,7 are connected to direct analog channels, while the rest are connected to the multiplexer's input lines. Power lines are used to measure current and voltage at various points where, for battery we can have 2 lines, one for current and one for voltage. The same holds good even for the solar arrays. Rest of them is used to monitor different current loads. Temperature sensors are used to maintain working temperature for components. Working temperature for various components is between 10^{o} Celsius to 40^{o} Celsius. Thus, in order to maintain this window temperature, heaters must be switched on or off according to readings of temperature sensors. So there is one temperature sensor each for battery, OBC card and Power card while the remaining two are spares which are used based on thermal analysis.

Sun sensors are used to measure the spin which should to be around 4.5 rpm and position of Sun. These sensors are placed at particular place in satellite. Rests of the channels are grounded.

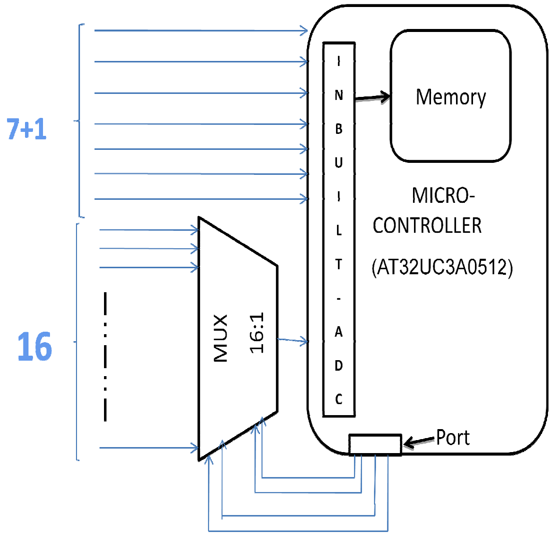

Fig 6: Analog data Acquisition Hardware Design

Before starting to acquire the analog data, necessary initialization and configuration should be made which is taken care of in the initial stage of mission. Figure 7 demonstrates the flowchart for analog data acquisition. The program runs for all available analog channels i.e., both for direct channels and channels from multiplexer. Two variables one for direct and other for indirect channels are used to iterate over all these channels. The flow of the program discussed as follows: Let us consider first variable as DIRECT and Second as INDIRECT. Both DIRECT and INDIRECT are set to 0 initially i.e., starting from channel 0 and copy the same to INDIRECT. If the value of DIRECT is less than 7, then, pass DIRECT as parameter to in-built functions to enable, start, collect data and disable or else make INDIRECT =7 and pass this as parameter for rest of the iterations(this is to iterate in multiplexer). When 7th channel is reached, vary the selection lines from 0 to 15. Once this is completed, store the data in particular address [3][4].

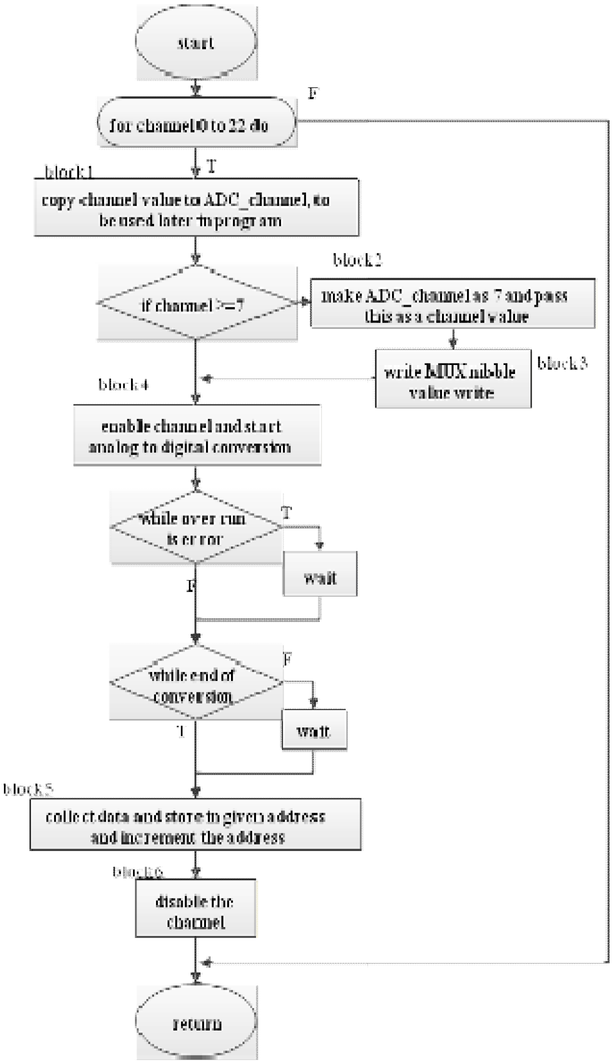

Fig 7: Analog Data Acquisition Flow chart

Digital: Digital data includes Command counter, Command, one bit status of the components and event flags. There is no such hardware design for Digital data acquisition part because everything is happening inside the microcontroller, nevertheless, we show the imaginary design in the following figure 8. We have to acquire the incoming command and command counter value which will be in Command register and command counter respectively. They are essential to obtain the latest command that is being executed. One bit status is used to indicate whether the components are on/off at any instant. Event flags are used to indicate when a particular event occurs, like, for example, completion of one major cycle. Once any event flag's status is recovered, it has

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to be reset using rest flag of the respective event flag.

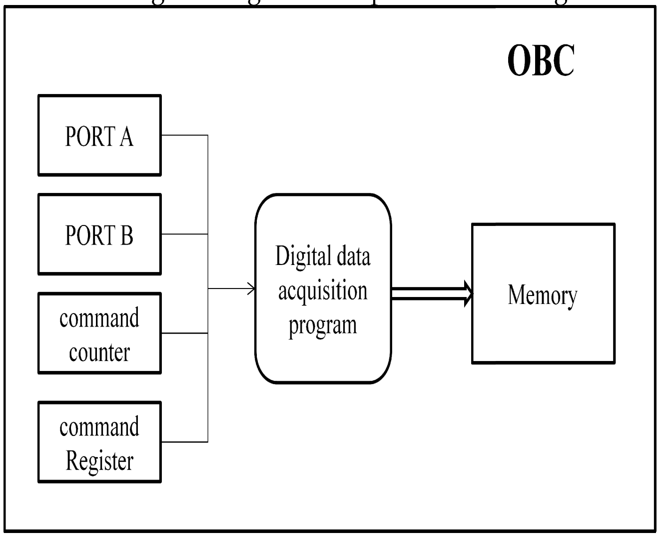

Fig 8: Digital data acquisition

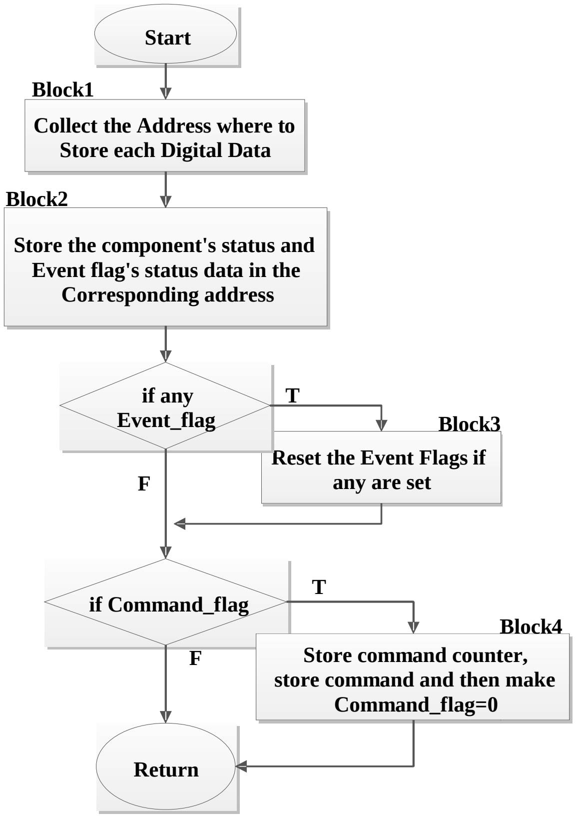

Fig 9: Digital data acquisition flowchart

The following figure 9 depicts the flowchart of digital data acquisition and program flow. Both port A and port B which is 32 bit long contain one bit status of component and event flag status i.e., 0/1. Since the entire port is stored at a particular address, both the component and event flag status are recovered by observing particular bits in that address[3][4].

Sections given below represent the sequence of operations that happens while acquiring the digital and analog data. Figure 10 represents the Analog data acquisition sequences. Once the sensor bestows data through an analog channel, this data is then converted into digital data. This is done by an in-built Analog to digital converter and stored in Channel Data Register (CDR) [1]. Later, this data can be collected and stored at a particular location. From this figure, we can clearly notice that at any instant of time the point of control is among the Sensors, Analog channels, OBC and Memory. The operation is initiated by OBC which then configures and initializes Peripheral ADC once the analog data are received, it then converts them to digital and then stores in particular address.

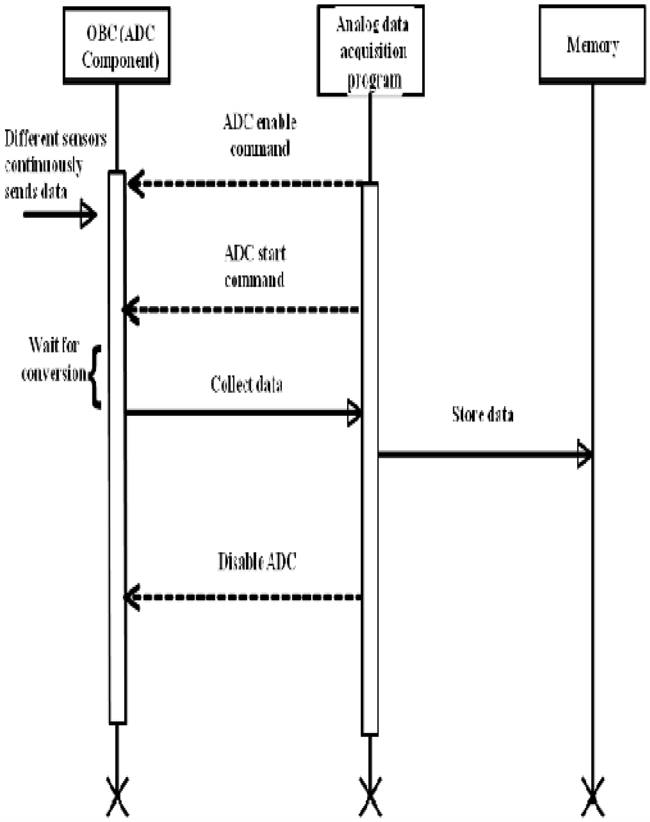

Fig 9: Analog data acquisition sequence diagram

Figure 11 shows the Digital data acquisition sequences which acquires four types of data i.e., Port A, Port B, Command counter and Command Register. In digital data acquisition at any instant of time the point of control is among OBC and Memory. OBC collects incoming Command, Command counter, PORT A and PORT B data. Various bits in Ports represent information about either flags or events that might have set or occurred.

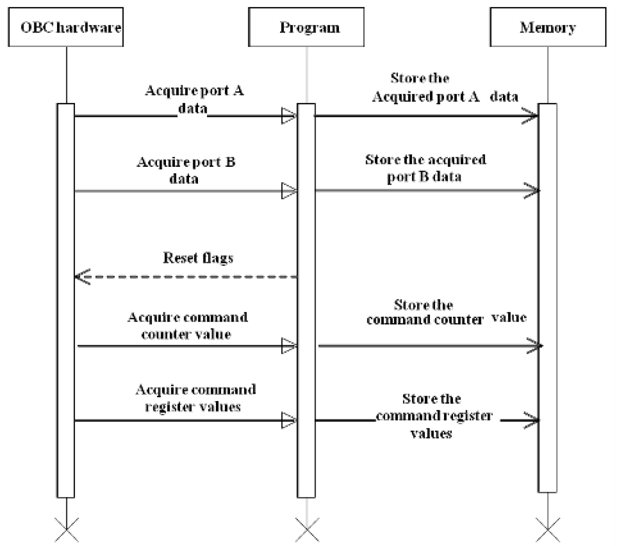

Fig 11: Digital data acquisition sequence diagram

Supervisor software is the central point which calls rest of the routines as and when needed. The main emphasis in building this software is to provide simplicity, mainly to make the learning curve as small as possible. As a result, one can see that there aren't too many complex logics or any sort of interrupts being used. When built, component by component, this is again an added advantage to the simplicity which abstracts the whole problem into number of small pieces.

IV. CONCLUSION AND FUTURE ENHANCEMENTS

Data acquisition was done without any distinction between analog and digital data. Though it was a straight forward approach for development, it was very cumbersome for searching particular data within a short period of time. By dividing the data acquisition into analog and digital we are avoiding confusion and making it easier to collect the particular kind of data. Further advantages of this separation include back-tracking the missing data due to erroneous situations, simplified debugging and testing and less wastage of memory due to incompatible- sized output from both components. One disadvantage of such separation is doing the same process twice in one major cycle which leads to increased number of instructions. The outlook is towards improving the process and finding alternatives to reduce the duplication.

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