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Multipurpose Microcontroller Design for PUGAS II

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Abstract

This paper will report on the past year's work on the development of the microcontroller design for the second Purdue University small self-contained payload. A first report on this effort was given at last year's conference by Ritter (1985). At that time, the project was still at the conceptual stage. Now a specific design has been set, prototyping has begun, and layout of the two-sided circuit board using CAD-techniques is nearing completion. A redesign of the overall concept of the circuit board was done to take advantage of the facilities available to students. An additional controller has been added to take large quantities of data concerning the shuttle environment during takeoff. The importance of setting a design time-line is discussed along with the electrical design considerations given to the controllers.

INTRODUCTION

This canister is Purdue's second venture with the Small Self-Contained Payload (SSCP) program. Both canisters will have in common the fact that they were controlled by a microprocessor-based electronics system. This is common to many Shuttle canisters. In our second design of a canister controller, we have taken advantage of new technologies available since the first Purdue canister was designed, and of new facilities provided for the students on campus. Specifically, the use of a low-power CMOS version of the popular Intel 8085 microprocessor, and a Computer-Aided-Design (CAD) system belonging to the School of Technology has greatly eased our design process.

OVERVIEW

The experiments planned for the payload include a particle detection block, a floppy disk block, a foam metal furnace and a moisture desorption chamber. Also, because the canister support structure is being built from a foam-resin compound, it is being considered as an experiment. Its physical response to the actual lift-off vibration will be recorded.

The first two experiments are passive and will require no inflight control. The desorption experiment requires only the opening and closing of a single valve. As support for these three experiments, temperature data will be taken from various parts of the canister over the duration of the time in space. This will record any abnormal conditions that might affect the materials used. It will also report on the efficiency of the passive thermal control system, which is based on a phase-charge in a high heat capacity salt.

The foam metal furnace heating procedure requires the most complicated control. This experiment consists of melting a sample of tin and zinc carbonate. The zinc carbonate will decompose into carbon dioxide which will diffuse homogeneously through-out the sample resulting in a new "alloy" with desireable weight and strength qualities for space construction. This experiment will be tied to one of the three relays under astronaut control. They will activate this relay when NASA can guarantee a 5-15 minute period of no vibration (i.e., no attitude control thrusts or orbital manuvering). The experiment requires both control actions to be taken and data to be stored. The current to the furnace must be regulated to melt the sample as smoothly as possible. One control line will turn the current on or off. This will be cycled to provide smooth temperature regulation. The controller will monitor the output from several temperature sensors to provide a thermostatic control. The heating cycle is not a simple on-off operation. Rather, for the experiment to work properly, the metal sample is brought up to a pre-selected temperature, held there for a few seconds and then allowed to cool.

Data will be stored from the temperature sensors for analysis later on the ground. The data will be taken very slowly prior to heating to establish initial conditions. Then as the critical heating point is reached, data will be taken at a faster rate. As the furnace cools, data will again be taken at a slower rate. Data will also be taken from a triaxial accelerometer during the melting and cooling in case the shuttle does experience some acceleration. This will be correlated with any anomolies in the metal sample.

Collecting the structure data has a requirement that increases the difficulty of implementation: the system must sense the time of lift-off without any signal from the shuttle crew. The most obvious indication of lift-off is the sudden increase of vibration. As this lift-off vibration is to be used as the signaling factor, vibrations from handling must be ignored by the controller. This is a critical decision for the hardware to make for if the wrong decision is made as to the validity of the collected data, the experiment will be a failure.

DESIGN DEVELOPMENT

At the commencement of this design, the following considerations were kept in mind. A system is needed to provide precise, reliable control of a variety of experiments. This system must be able to monitor the canister conditions, make decisions and store data for retrieval after the shuttle returns to Earth. Because Purdue hopes to continue its involvement with the SSCP program, it would be desirable that the final design could be easily adapted to future needs. Time would be saved if a system was designed using materials with which students were already basically familiar. It was decided that a single board micro-computer met the above requirements in the best manner when also considering space, weight, and power.

Reliability was a major concern in this decision. The use of a single control system has the drawback that one fault can jeopardize the entire canister results. An initial choice was made to have a controller for each experiment with a master system guiding them and watching for any malfunction. This idea was dropped for two major reasons. First, hardware interfacing and software for the master controller would be a monumental task to complete and to guarantee to work under a variety of conditions. Second, a failure in only the master system could still accidentally shut down all of the individual controllers. Our final design uses only the three independent controllers, with one each for the structure, furnace, and desorption chamber. The desorption controller will also take canister temperature data for the duration of the flight. If one of the controllers malfunctions, only part of the canister's experiments will fail.

The controller taking the temperature data will run from five to seven days. Even at the low levels of power used by integrated circuits, over this period of time the total is large. Because batteries make up the majority of the bulk of the canister's weight, low power usage is a must. For this reason it was decided to use CMOS integrated circuits. Since the flight of Purdue's first canister in 1983, a CMOS version of Intel's 8085 microprocessor and related family of circuits has been introduced. In addition, Purdue currently uses the 8085 for its introductory microprocessor course. Thus, many of the students involved in the controller hardware and software design are already familiar with the 8085.

The basic design, shown schematically in Fig. 1, includes the 8085, 8k of ROM for the software, 8k of EEPROM for data storage, an eight bit analog to digital converter, a mc146818 realtime clock for system timing and an 8155 which provides 256 bytes of RAM, a timer, and three input/output ports. External communication is done through one of the ports on the 8155. Adding a communications chip to the prototype to ease the loading and debugging of software was considered. However, it was felt that the prototype should be an exact duplicate of the final flight hardware. In this way there would be little doubt that the final version would work.

Another of the ports of the 8155 is used as an internal control signal generator. The EEPROM selected has six modes of operation, including various write and erase modes as well as read. The select lines to choose one of these states come from this port. This eliminated the need for complex decoding of address lines to select the proper functions. This produced the benefit of reducing the random logic to a level where it can be programmed on one Programmable-Array-Logic chip instead of using several generic chips. This reduces power and space and increases reliability.

The timer of the 8155 performs a very important function as a "watchdog". The controller microprocessors are exposed to a very rugged and unpredictable environment. If the processor were to "glitch" due to a transient in the power supply or radiation, its internal registers might be altered. The processor might freeze up, execute non-program data or do any number of unpredictable actions. The timer output is connected to one of the interrupt pins of the 8085. The software will be written in such a way that when a procedure has been completed, a flag will be set and the processor will pause. The timer will bring the processor out of the pause and check the flag. If the flag was set then the software has probably been running correctly. If the flag is not set then the interrupt routine will try to recover from the error.

It is felt that the only way to insure that the returned data in memory is valid is to keep a log record of all actions taken in the EEPROM. If power is removed or the controller stops for some reason then it will be known exactly where this occurred. The watchdog routine will also use this log to determine the status of the system before an error occurred. The log entries will include the time from

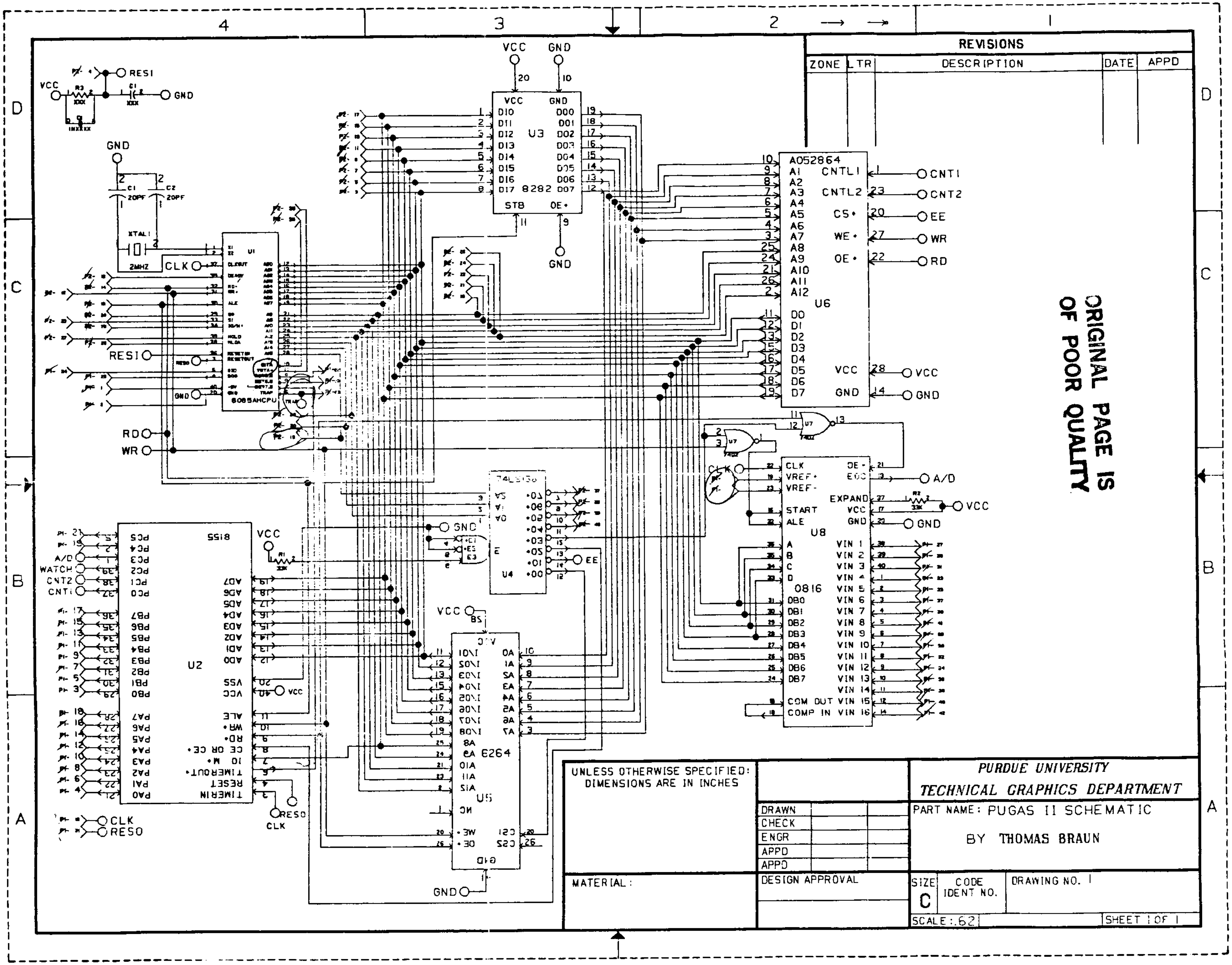

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Fig. 1. Schematic of the prototype multipurpose microcontroller for PUGAS II.

the real-time clock chip and a code for the action completed.

The furnace and desorption controller are identical. The structure controller has been modified to perform its special function. To study the response of the structure to vibration, Fourier analysis will be performed on the data taken from strain gauges mounted on the structure fins. This requires that the sensors be sampled at least 8000 times per second. This is to avoid problems in the analysis with high frequency vibration. As sixteen channels are to be monitored, the resulting 128kHz sampling rate is beyond the ability of the microprocessor and single A/D converter system. An 8257 direct memory access chip will be used to bypass the processor and directly transfer data from a group of A/D converters to a set of banked memory blocks. The huge amount of data recorded will require at least 128k of battery backed-up memory. This memory will be selected in 32k blocks by the same 8155 port that controls the EEPROM.

Of great concern is the backing up of the memory. EEPROM memory is too slow to use for this application and would require a large number of chips. A combination of a battery and five Farad capacitors will be used to backup static memory chips. A very simple analysis of the data will be done in space and stored in the EEPROM so that data will be retained if the memory fails.

To activate the controller, a set of vibration switches will trigger an SCR switch. This device will latch power to the controller until it is shorted out under software control. In series with the trigger switches is a mercury switch. Because the canister is stored vertically but launched almost horizontally, this switch will be mounted at an angle that prevents ground shocks from activating the experiment. An additional safety measure will be a pressure gauge. This gauge will be vented to the outside of the canister. If the pressure drops, then it will be assumed that the shuttle is climbing into space. Once the software has determined that good data has been measured and has done the preliminary analysis, the processor will turn itself off permanently. This will be done by blowing a small fuse on the power supply line. In this way this unit cannot be reactivated. If the controller is activated accidentally, it will temporarily shut off by shorting the SCR. This will break the connection. The controller can still be reactivated by the next shock.

The vibration experiment was originally designed as a separate circuit board that would piggyback to a controller identical to the others. Through the use of the CAD system, the design was stripped of the unneeded slow A/D converter and the real-time clock and condensed to one circuit board. Because the CAD computer can easily generate the modified circuit board patterns, custom design of the third controller was a practical consideration. This would not be practical if the drawing was to be done by hand.

All of the controllers will be able to communicate to the outside of the canister through the 8155 port. This is essential so that the computer hardware can be checked after it has been installed into the NASA canister at the launch site. The software will include routines to check the hardware and sensors. This will be done through the use of an IBM PC as a terminal for the controllers. The first action a controller will take upon being activated will be to check a control line to see if it is in space or on the ground for testing.

PRESENT STATUS

Most of this design work was done by the spring of 1986. Due to the fact that this is a student project, there is a continuous influx of new workers. New members bring in new ideas and methods of doing things. We found that to keep the project moving at the necessary pace, a date needed to be set after which no changes would be done to the design. Doing this generated the necessary activity to complete the design. Setting such dates is important if work is to be completed.

Currently, we are in the process of designing and choosing sensors, and writing software. Because the controllers are essentially identical, most of the software will be common to all of them. This includes such routines as the watchdog check, communications, log updating, and system timing. Rules are being generated for the code that governs the unique operations of each controller. These vary from being simple for the desorption controller to very complicated for the structure experiment. A prototype has been built and is being debugged. We hope to have all of the controllers completed by the end of the year.

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