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Design of Digital Logics for Automatic Temperature Control in Spacecrafts

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Abstract— Automatic Temperature Control (ATC) maintains the temperature of a given node or location within the temperature limits by ON-OFF control of the heaters on spacecrafts. The observation of satellites thermal behavior is a continual process that foresees the temperature distributions throughout the components and subsystems, all of which need to remain in most favorable temperature range for proper performance. The proposed system aims in designing the digital logics for Automatic Temperature Control in spacecrafts by using the heater switching logic. Telecommand is the command sent from ground station to the spacecraft. Telemetry is the data sent by the satellite to ground station. The heaters are organized as groups in spacecrafts and the Solid State Switches are used for switching the raw bus (high voltage) to the heaters. The heaters play the key important role in protecting the spacecrafts components under the cold-case environmental conditional and also to warm up the components to their minimum operating temperatures before turned ON. The temperature value is compared with the lower and upper threshold point (LTP and UTP) values. When the temperature value is above the UTP value, the heater is made OFF and when the temperature value is below the LTP value, the heater is made ON. This way the heaters are controlled.

Index Terms— Automatic Temperature Control; ATCS; PTCS; Telecommand; Telemetry

1 INTRODUCTION

In the spacecraft design, the Thermal Control System (TCS) plays a very important role. The main objective of "thermal control design" is to provide the proper heat transfer between all spacecraft elements so that temperature sensitive components will remain within their specified temperature limits during all mission environmental conditions. "A spacecraft can either passively or actively manage its thermal behavior". Passive Thermal Control Systems (PTCS) are highly attractive to the satellite designers, because they are associated with low cost as well as low risk, and have proven reliability. If the spacecraft is able to preserve thermal stability without additional power requirements then it is considered "passively controlled" [1]. This method integrates thermal blankets such as multi-layer insulation (MLI) [1], thermal coating, and thermal transfer via heat pipes, washers, bolts, and spacers. The system is actively controlled by Active Thermal Control System (ATCS), when thermal control is accomplished using additional power requirements. While PTCS are simpler and more reliable, ATCS are associated with higher precision and have been shown to be more effective for regulating thermal control [1]. However, for temperature sensitive devices such as batteries, cameras, etc., engineers are able to equip spacecraft with electric heaters and coolers to maintain operational temperatures. Thermal control is also necessary to keep specific components within a specified temperature stability requirement, to ensure that they perform as efficiently as possible. The main aim of this paper is to design the digital logics for Automatic Temperature Control in spacecraft by implementing heater switching logic.

2 NEED OF THERMAL CONTROL SYSTEM

Thermal Control System (TCS) provides the convenient temperature environments for various subsystems during different phases of satellite life. Heaters are used for temperature control of each system. The Thermal Control System is required to provide the proper heat transfer between all the spacecraft elements so that the temperature sensitive components will remain within their specified temperature limits during various environmental conditions. Thermal Control System is essential to achieve the optimum performance and success of the mission because if a component is subjected to a temperature which is too high or low then its performance could be affected or it could be damaged. Thermal Control System is also needed to keep the particular components within their specified temperature stability need, so that they perform as smoothly as possible.

3 AUTOMATIC TEMPERATURE CONTROL IN SPACECRAFTS

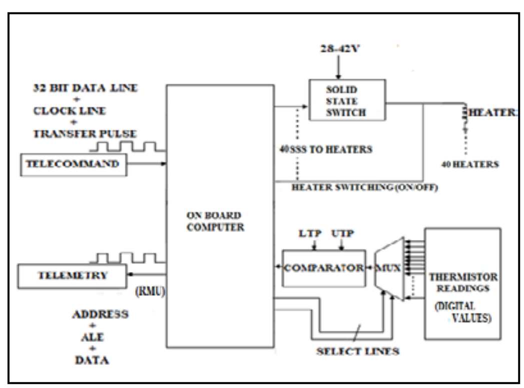

Fig. 1. Block diagram of Spacecraft Thermal Control

The Heaters are organized as groups in spacecraft. There are 40heaters which are arranged in 5 groups named group1, group2, group3, group4 and group5. Each individual group consists of 8 heaters. Each group has the enable/disable provision. The solid state switches are used to switch the raw bus

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(28-42v) to the heaters. Only if the particular group is enabled and the raw bus is connected then only the heaters of that group will be turned ON or OFF based on the Telecommand sent. The block diagram of Automatic Temperature Control system of spacecraft is shown in fig. 1 and each block is explained in detail below.

3.1Telecommand

Telecommand is the command sent from the ground station to the spacecraft which is 32 bit wide. It is normally sent as asynchronous data packets. TC consists of 32bit data line, clock line and Transfer Pulse (TP).The data gets latched with the positive edge of the TP. The latched data is decoded onboard and the decoded data consists of the following

1. ATC enable/disable command
2. LTP/UTP command for heaters
3. Heater ON/OFF command
4. GRP ON/OFF command

When the data is decoded, the MSB first 2bits indicates the status bits. If the status bit decoded has the following values as shown below it indicates that the “Telecommand” sent was for the following different purposes

1. 00-ATC Disable command
2. 01-command to set LTP value
3. 10-command to set UTP value
4. 11 -ATC enable command

3.2 Solid State Switch

There are 48 solid state switches which are connected to 48 heaters. These solid state switches will switch the raw bus (high voltage) to the heaters. The solid state switch will require the level signal for its operation. The Solid State Switch (SSS) will excite on receiving the “heater ON command”, conducts and switches the raw bus to the heaters. On receiving the “heater OFF command”, the excitation to SSS is removed.

3.3 Comparator

The upper and lower temperature limits (UTP/LTP) for heaters are programmable. The UTP and LTP value for each of the individual heater is stored in the “set-point table” of heaters. The UTP and LTP values are 10 bit wide. The “set-point table”[2] is nothing but the look up table which is like a memory. The thermistor readings (digital values) which are given as inputs are compared with UTP and LTP value. If the temperature value is less than the LTP value, the heater is turned ON and if the temperature value is greater than the UTP value the heater is turned OFF. This way the heaters are turned ON/OFF and heater switching logic is implemented.

4.4 Telemetry

“Telemetry”(TM) is the data sent by the satellite to the ground station. “Remote Multiplexer Unit” (RMU) interface is provided to minimize the harness of transfer of telemetry data from subsystem. The telemetry data are sent in packets. “Telemetry “consists of address, ALE, data. This Telemetry data is decoded and will give the following information

1) Heater ON/OFF state
2) Temperature
3) Other required statuses

4 Design ofDifferent Logics

The different digital logics designed to achieve the spacecraft thermal control are discussed in detail in coming sections.

4.1 ATCDisable Logic

The ATC disable logic indicates the manual control of different heaters on spacecraft when the “Automatic Temperature Control” is disabled. The Block diagram of ATC disable logic is shown in the fig .2. The “TP” is generated for every 16ms based on the clock signal. When positive edge of transfer pulse arrives the data gets latched. Once the data is latched the decoding of the latched data takes place. The status decoder decodes the status bits. When the status bits are “00”, it indicates that “ATC” is disabled. Next the group encoder will encode the heater groups. There are 5 groups and each group has the group enable and disable provision. Then the Raw bus decoder will decode the raw bus, and indicates which group raw bus is enabled. Suppose if the group1 is enabled and raw bus of group1 is enabled, then the heaters 1-8 can be manually turned ON. If the group is enabled and the raw bus is not connected or vice-versa then the heaters will remain OFF itself.

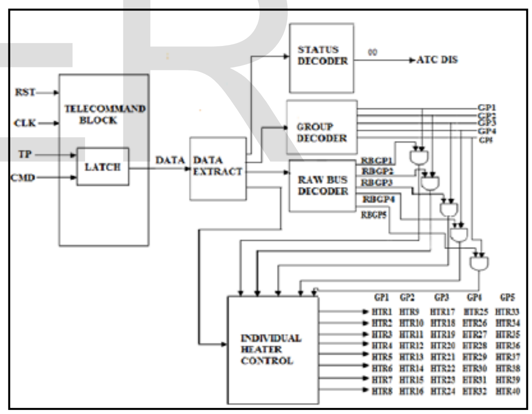

Fig. 2. Block diagram of ATC Disable logic

4.2 Setting the new values of LTP and UTP

The “threshold points” i.e. lower temperature limit and upper temperature limits for heaters are called LTP and UTP. The LTP and UTP values are stored in “set-point table” .The set-point table is a look up table in the form of memory which is used to store the values of LTP and UTP. The LTP and UTP values are programmable. Initially the LTP and UTP values are stored and these values can be changed or updated based on the TM data obtained. The block diagram of Logic for setting new values of LTP and UTP is shown in the fig .3. Once the data is latched, decoding of the data takes place. The status decoder will decode the status bits. If the decoded status bits are “01” it indicates that the command sent was to set the new value of LTP for heater. If the decoded status bits are “10” it indicates that the command sent was to set the new values of UTP for heater.

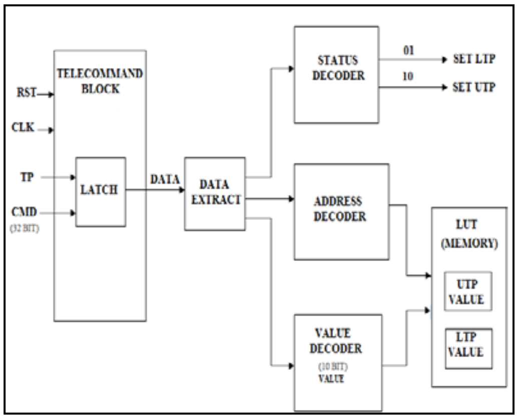

Fig. 3. Block diagram of setting new values of LTP and UTP

4.2 ATC Enable Logic

The third logic implemented is the ATC enable logic. ATC enable logic indicates the "Automatic Temperature Control" of spacecraft by heater switching logic. The block diagram of ATC enable logic is shown in the fig .4.

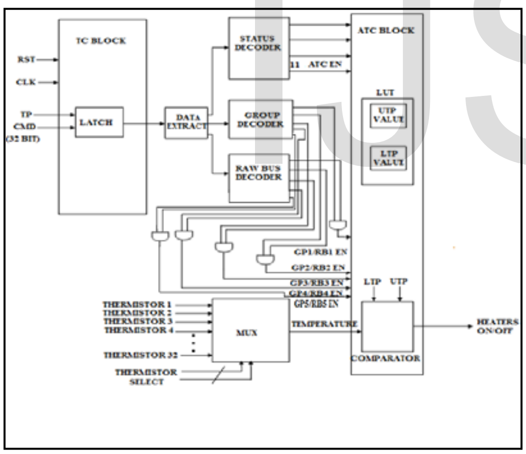

Fig. 4. Block diagram of ATC Disable logic

The transfer pulse is generated for every 16ms. Based on the transfer pulse the data gets latched. Once the 32bit data is latched decoding of the data takes place. The status decoder will decode the status bits .When the ATC is enabled the status bits turn "11". Group decoder will decode the group and indicates which group is enabled. Raw bus decoder will decode the raw bus and indicates which group raw bus is enabled. Both the group and the raw bus have to be enabled to control the heaters of that particular group. Thermistor readings (digital values) are given as input to the ATC block. The multiplexer is used to select one particular thermistor reading which gives the temperature value. The LTP and UTP values are required to be set before the ATC is enabled. These values are given as inputs to the comparator .When the ATC is enabled the comparator will automatically compare the LTP, UTP and temperature values and based on the comparison heaters are turned ONN/OFF.

5 Results

The Simulation results of the logics implemented are shown below. The user interface is developed using the System Generator 14.5 to give the Telecommand and to observe the heater status of the individual heaters.

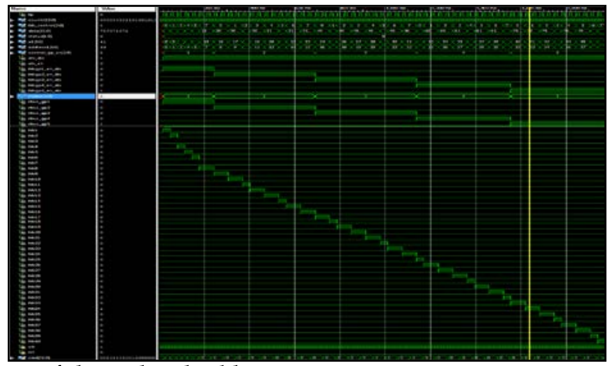

Fig. 5. Simulation results of ATC Disable logic

Fig. 6. Simulation results of setting new value of LTP and UTP

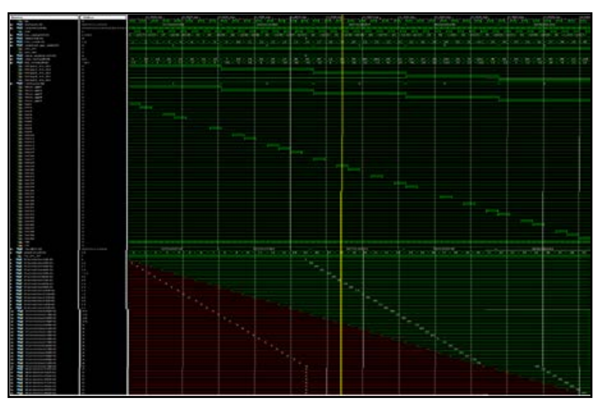

Fig. 7. Simulation results of ATC enable logic

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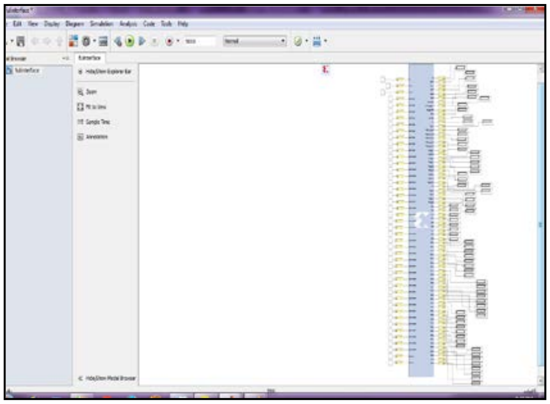

Fig. 8. User interface model

4 CONCLUSION

Different digital logics are designed to achieve the "spacecraft Thermal Control automation" which is necessary to maintain the temperature range of various electronic instruments and the equipments onboard. The heater switching logic implemented is used for controlling the various heaters which are organized in different groups and it also controls the unnecessary switching ON of heaters, which reduces the power consumption in real time. By implementing the ATC disable and ATC enable logic in spacecraft Thermal Control System both the manual and automatic control over heaters are possible.

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