Thermal and telemetry module design for satellite camera

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Abstract

Under the hostile influence of the extreme space environmental conditions due to the deep space and direct solar flux, the thermal control in space applications is especially of major importance. There are tight temperature range restrictions for electro-optical elements while on the other hand there are low power consumption requirements due to the limited energy sources on the spacecraft. So, we usually have strong requirement of thermal and power control module in space applications. In this paper, the design concept of a thermal and power control module in the MSC(Multi-Spectral Camera) system which will be a payload on KOMPSAT Ⅱ is described in terms of H/W & S/W. This thermal and power control module, called THTM(THermal and Telemetry Module) in MSC, resides inside the PMU(Payload Management Unit) which is responsible for the proper management of the MSC payload for controlling and monitoring the temperature insides the EOS(Electro-Optic System) and gathering all the analog telemetry from all the MSC sub-units, etc. Particularly, the designed heater controller has the special mode of "duty cycle" in addition to normal closed loop control mode as usual. THTM controls heaters in open loop according to on/off set time designed through analysis in duty cycle mode in case of all thermistor failure whereas it controls heaters by comparing the thermistor value to temperature based on closed loop in normal mode. And a designed THTM provides a checking and protection method against the failure in thermal control command using the test pulse in command itself.

Keywords: MSC, PMU, THTM, Heater, thermal control

1. Introduction

The MSC is a primary payload for a KOMPSAT-2 satellite and will perform the main mission such as surveillance of large scale disasters and its countermeasure, acquisition of high resolution images for GIS, composition of printed maps and digitized maps, etc. Under the hostile influence of the extreme space environmental conditions due to deep space and direct solar flux, the thermal design is especially of major importance in MSC system design. There are tight temperature range restrictions for electro-optical elements while on the other hand there are low power consumption requirements due to the limited energy sources on the spacecraft. The thermal design in a payload has to address heat removal in hot condition one hand and to prevent under-cooling in cold condition on the other hand. These contradictory tasks are accomplished by design of heat removal system parameters and the temperature heaters control. The temperature control system is based on heaters on the sensitive element through heaters on/off control. The heater control for the MSC is performed by the THTM board in the PMU with thermistors as sensing elements. This paper contains the design contents of THTM and describes its possibility of application to other satellite camera system.

2. MSC electronic System

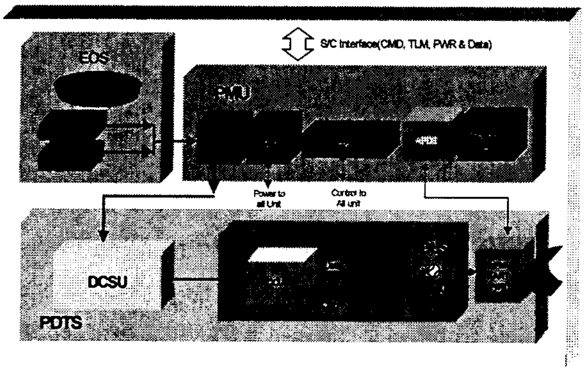

Figure 1. MSC Block Diagram

The MSC payload consists of EOS, PMU, PDTS(Payload Data Transmission Subsystem) and interconnection harness as shown in Figure 1. The EOS consisting of OM(Optical Module) and CEU(Camera Electronic Unit) is to obtain data for high resolution images by converting incoming light into digital stream of pixel data. The PDTS, which comprises of the DCSU(Data Compression & Storage Unit), the CCU(Channel Coding Unit), the QTX(QPSK Transmitter), the APM(Antenna Pointing Mechanism) and Antenna, stores and transmits these digital image data to the ground station through X band antenna. The PMU, consisting of several sub-assemblies with an architecture that supports a cold redundancy concept, provides electrical and software interfaces between the MSC and the spacecraft, controls all the MSC subsystem by the ground station commands and reports all the SOH(State Of Health) telemetry to the spacecraft. The PMU consists of the SBC(Single Board Computer), the THTM, the NUC(Non-Uniformity Correction board), the APDE(Antenna Pointing & Driving Electronics Board) and the PSM(Power Supply Module). Especially, as the main controller of the MSC payload, the SBC provide serial communication channel to MSC external subunits and other subunits inside PMU like THTM. It also executes arriving commands from OBC, receives telemetry data from THTM and sends it to the OBC, and performs antenna control and self-test, etc.

3. Design of THTM

As mentioned before, the THTM resides inside the PMU of MSC. Its circuitry is an autonomous circuitry that operates since thermal power had been applied to MSC even if other power lines of MSC(e.g PMU and others) are switched off. The THTM is mainly used to control and monitor the temperatures of the EOS(Electro Optic Sub-System) and switch on or off the power of MSC subunits according to the command from SBC. It also gathers all analog telemetry data from all MSC units for sending later to the Ground Station. In this chapter, the thermal design concept in MSC and then the design content of THTM is described in detail.

3.1 Thermal Design Concept in MSC

The thermal control and design of the MSC shall be capable of obtaining proper thermal conditions for each component and unit of the MSC under various environmental conditions. These conditions shall be set based on the definitions within the MSC system specification and particularly fulfilled by relevant interfaces. The thermal design concept is primarily based on passive thermal control, but active thermal control by heaters is applied on thermally critical units such as EOS. The thermal design makes use of the elements such as MLI blankets, surface finish/coating, conductance control elements, tapes, and thermal control with heaters and thermistors. The passive thermal control shall be achieved by covering the HSTS with MLI except the opening entrance for the OM and by connecting thermal conductors to the EOS cooling unit for CEU. Active thermal control shall be required in

"S/C Sun mode" in order to prevent over-cooling of the HSTS(High stability Telescope Structure), the mirrors and the lenses. It include heaters and thermistors, as shown Figure 2, to perform close loop thermal control.

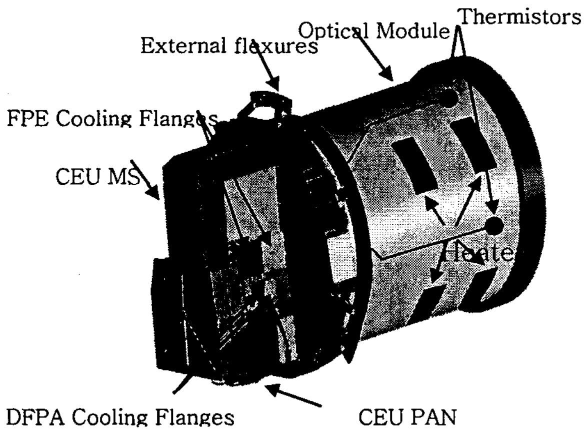

Figure 2. EOS heaters and thermistors location

Table 1 shows the heaters set point for the different operating condition. In contrast to the MSC normal operation condition in which normal MSC operation runs, MSC system except THTM is not powered in survival operation condition. And the Out-gassing is a special mission for the decontamination of mirror. All the set points are programmable except for survival set point. Heaters operating logic is as follows: first, unit temperature is read by THTM and then averaged; second the average is compared to the set points; and finally according to the comparison results, the heaters are turned on, off or not changed. Thermal control modes include two regular(close loop) modes of normal and survival mode. The purpose of both modes is to prevent damage to the unit or to provide suitable temperature for proper operating. The only difference between those modes is the set points. In both modes the temperature of all the units is controlled, but the predicted temperatures of some units are higher than the off-set point without active heating as indicated with mark * in Table 1. Duty cycle mode is a special mode in sense that this is a "local" mode, which can apply to every unit alone. It shall be used in case all the thermal sensors of a particular unit are malfunctioning. In this mode the heaters of the specific unit will operate in a duty cycle in order to prevent damage to the unit. Since there are no operating sensors for this unit, the thermal control shall be in open loop. Mirrors Out-gassing mode is to clean the mirror and not to keep the mirrors in proper temperature. This mode is implemented by changing the mirrors' thermal control set points to out gassing values.

Table 1. EOS heaters set point

Unit	Normal On/Off [°C]	Survival On/Off [°C]	Out-gassing On/Off [°C]
PAN Detector Ass.	5 / 8	-5 / -2	5 / 8
MS Detector Ass.	5 / 8	-5 / -2	5 / 8
Primary Mirror	-20 / -17*	-20 / -17	46 / 49
Secondary Mirror	-20 / -17*	-20 / -17	46 / 49
Telescope Tube	-20 / -15*	-20 / -15	-20 / -15*

3.2 THTM H/W

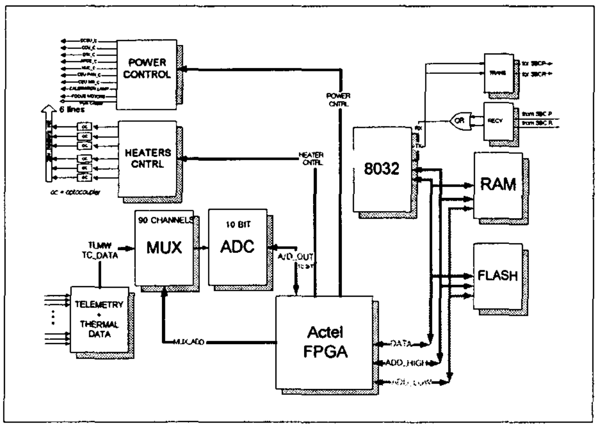

Figure 3. THTM function block diagram

THTM, as its name implies, gathers telemetry information of each units and performs the thermal control on the EOS module as its main purpose. It also produces the power switching pulses, being intensified by drivers, for the external units and internal other units within PMU, and send PYRO ignition pulse which is amplified by BACKPLANE drivers. In addition to these, the board shall activate the focus motors when required.

Table 2. Memory allocation

ID	Address
Code Flash	0000h – 7FFFh
I/O	8000h – BBFFh
RAM	BC00h – FFFFh

THTM board contains same 2 function blocks of primary and redundancy to support cold and hot redundant design concept while sharing interface connectors and interface logic for telemetry. As shown Figure 3, it comprises 80C32 CPU, RAM, Flash ROM, Actel FPGA, A/D converter, communication between SBC and THTM with full cross strap the general function blocks. Its memory allocation is represented in Table 2, where the I/O memory range is divided into various I/O unit's address such as heaters, A/D converters, PYRO device, camera focusing motor driver, calibration lamp driver, etc.

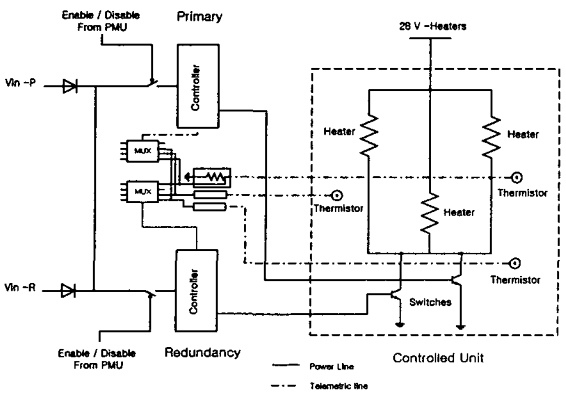

Figure 4. Heaters control diagram

Heater control logic is shown in Figure 4 and its redundancy is achieved by allocating at least four heaters for every control area. The concept is that even if one heater is fail, the others will produce enough heat to prevent under-heating. Furthermore, when it generates heater control command, test bit toggling every command time is issued periodically within command word itself to detect and prevent a possible failure of control command that will keep one of heaters active or inactive. The control logic decides whether there is some problem with control command if this test bit doesn't toggle for 50msec. THTM enhances the reliability of the control system in this way. The relay control signals used for power control of external unit and for PYRO, ASU position control are generated through FPGA and signal amplifier to meet specification of each relay and these circuits have protection for possible noise such as spike coming from relay.

3.3 THTM S/W

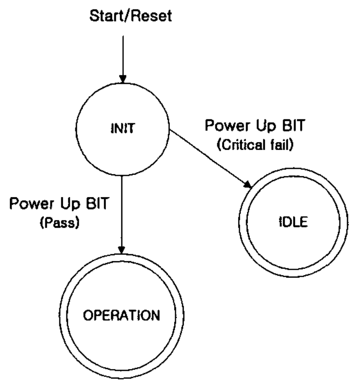

Figure 5. State Transition Diagram

The THTM S/W runs under the 3 operation modes of INIT, OPERATION, and IDLE as shown Figure 5. Whenever the THTM is powered, it enters into INIT mode to do all necessary steps for the normal operation of THTM including initialization of H/W and S/W, and BIT. According to the results of component initialization and power-up BIT, THTM enter into different modes. With the critical failure of power-up BIT, THTM immediately enters IDEL mode and remains in this mode until it is turned off by the SBC. Once it finishes the initialization successfully, it automatically enters OPERATION mode. In operation mode, THTM handles all the periodical tasks and stays in this mode in a main loop until it is turned off by the SBC. Its main tasks are to control the temperatures at sensitive areas inside EOS by gathering all thermal data from EOS thermistors and switching on/off necessary EOS heaters upon temperature setup table, and to gather analog telemetry from all MSC units and report it to the SBC upon request, to handle communication with SBC, to do all switch control including power switch, to handle the watchdog and system timer, and to perform BIT of the THTM.

Table 3. Software capabilities vs. operation modes

Mode / Capability	INIT	OPERATION	IDLE
[redacted]	X	X	
[redacted]	X		
[redacted]		X	
[redacted]			X
[redacted]	X	X	
[redacted]	X	X	
[redacted]		X	
[redacted]		X	
[redacted]		X	
[redacted]	X	X	
[redacted]	X	X	
[redacted]	X		
[redacted]		X	
[redacted]		X	

The Table 3 lists the capabilities of the THTM S/W which are required to perform the S/W requirement according to operation mode. The C_MANAG capability handles all the activities related to the THTM modes of management according to modes of operation. To support various operation modes, it decomposes into the 3 sub-capabilities: C_INIT, C_OPERATION, C_IDLE. The C_INIT capability handles all the activities related to the THTM initialization process in INIT mode with power up. C_IDLE capability is to disable the watch dog reset and halt the processor because THTM behavior is unpredictable due to the critical failure in THTM. The C_ OPERATION capability handles all the activities related to the THTM normal operation process in OPERATION mode. It requests various capabilities to perform normal operations such as C_TIMER for getting system time, C_COMM for communication between SBC and THTM, C_TELEMETRY_CTRL for telemetry data gathering, C_THERMAL_CTRL for appropriate thermal control, C_POWER for sub unit's power control, and C_BIT for periodical background and operator initiated test.

4. Computer simulation

This simulation results in Figure 6 is about heater control logic and shows how the signal PAN_HTR is generated using heater control command containing test pulse at the 7th location from LSB *in a word. The input command word* DATA_IN is triggered into temporary buffer, PAN_HTR_BUFF at the rising edge of signal WR when address, A_H, is "84h". The bit # 6 of this word in a buffer is triggered into signal PAN_HTR_TST1 and PAN_HTR_TST2 with one and two clock, DIV_CLK, delay each to make signal TRANSITION active indicating that consecutive command word has toggle in the test pulse. This signal causes reset to signal, HTR_TST_CNT, used for checking if there is a toggle in the test pulse for last 300ms. If not, it results in assigning zero to PAN_HTR, which shall open H/W control signal for heater. As shown in simulation result, the input command is buffered when an address is "84h" and the heater control signal is generated according to the input command word by following logic: PAN_HTR(3) from PAN_HTR_BUFF(7), PAN_HTR(2) from PAN_HTR_BUFF (5), PAN_HTR(1) from PAN_HTR_BUFF(3), PAN_HTR(0) from PAN_HTR_BUFF(1).

5. Conclusion

In this paper, we described contents of the THTM design in MSC which is used for thermal control, telemetry gathering and power control of subunits in MSC, etc. All these functions are performed through FPGA control signal being commanded by SBC and simulation results was explained to show how to generate one of these FPGA signals. The designed THTM has a various characteristics. First of all, this unit has a special thermal control mode, in addition to normal closed loop temperature control mode, called duty cycle mode for the situation in which all thermistor in specific zone fails and thermal control is done using switch on/off time predefined for this mode. Furthermore, command word itself for heater control contains the test pulse that toggles every command time so as to check there is a problem with issuing a command by checking it. Both scheme enhance the reliability of the control for heater. And a designed THTM could be applied easily to other systems thanks to its general design concept by changing some set point for system control.

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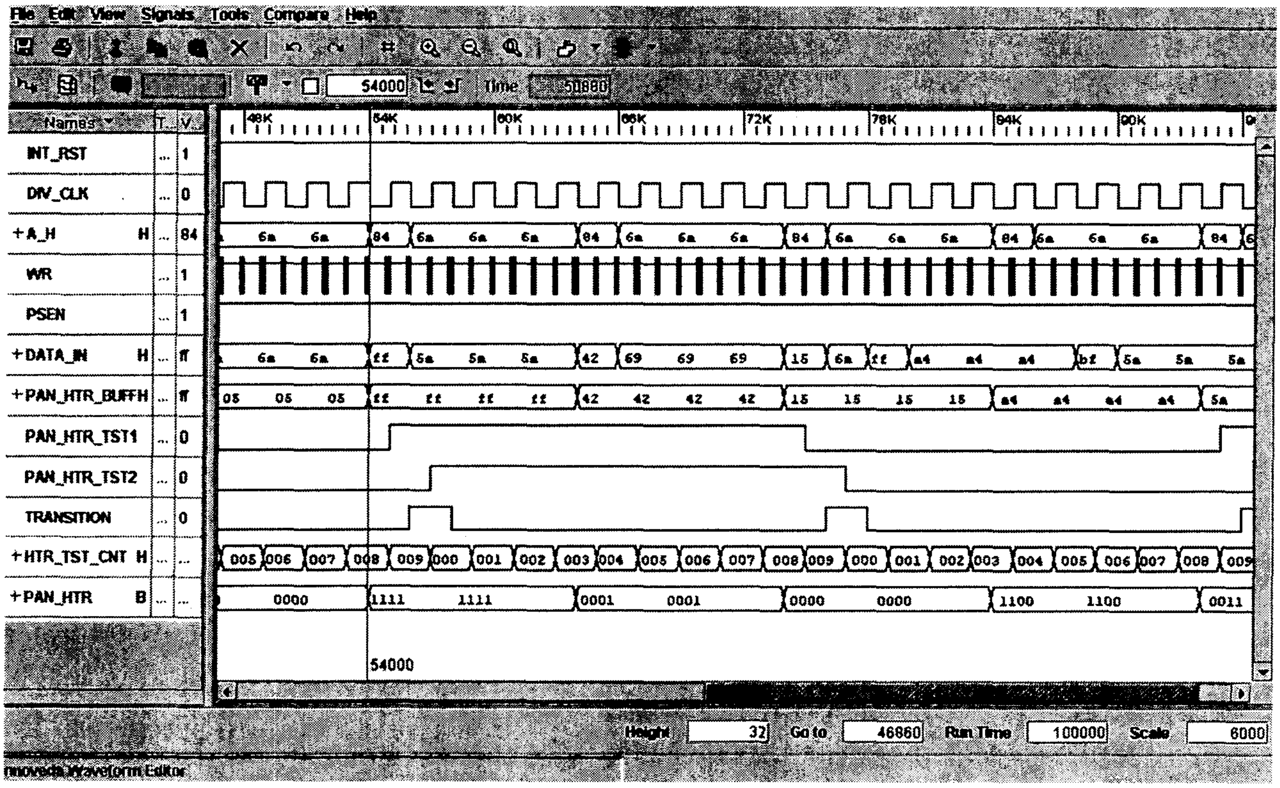

Figure 6. Simulation results for heater command signal generation