Dynamic Active Thermal Control of a LEO Nano-satellite based on its Mode of Operation

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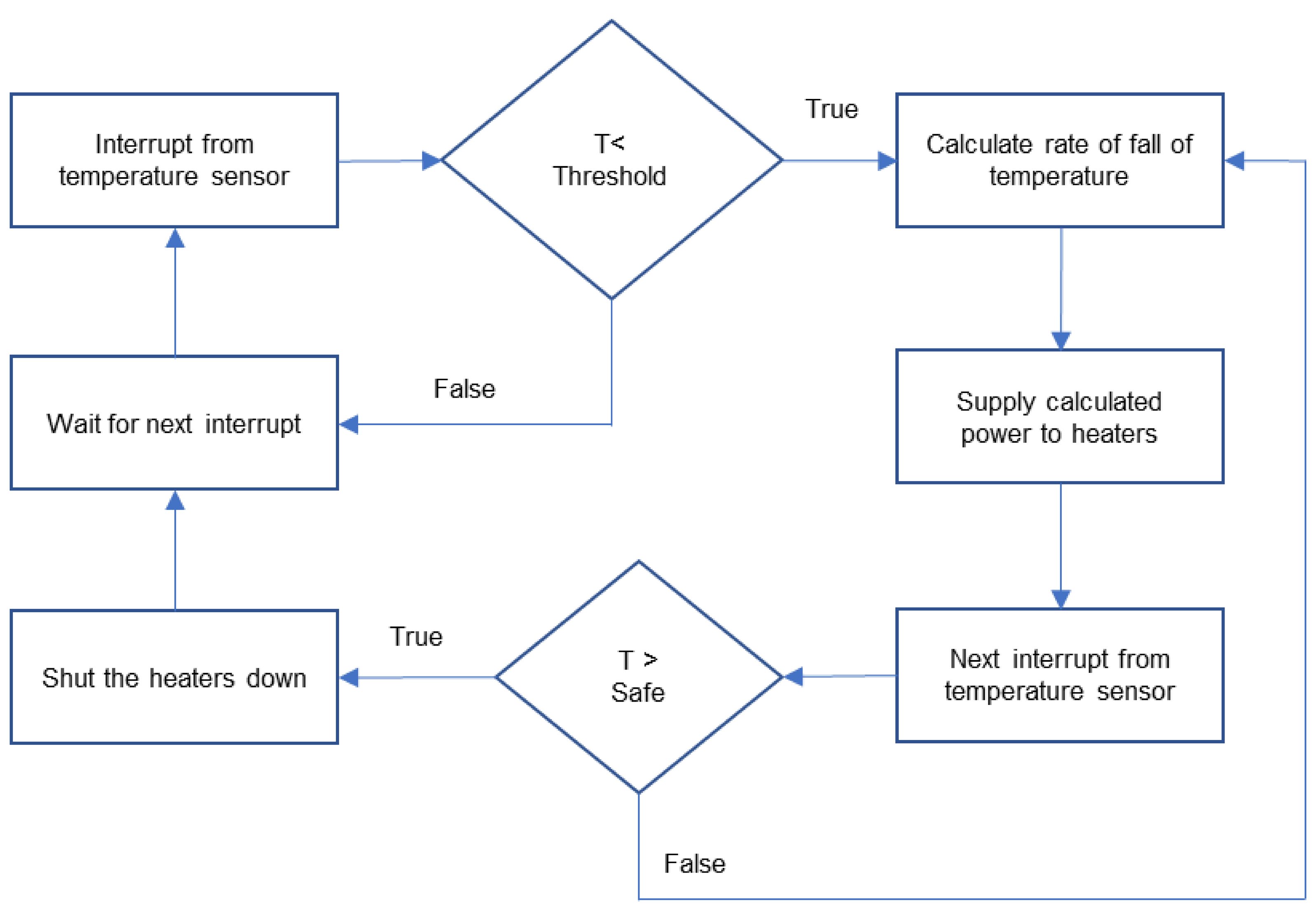
ABSTRACT

The paper explains the design of an active thermal control system which would work as per the needs of the current operational mode of the satellite. The modes of the satellite have been classified into two major groups: the normal modes and the emergency modes. The modes of particular interest to the thermal control system are three of the emergency modes and the image capture mode, which is one of the normal modes. The electrical loop of the system will be dynamically controlled by the TI MSP430 microcontroller of the Electrical Power System (EPS) as per the present mode of operation set by the Onboard Computer (OBC). The dynamic control loop ensures that the imager is heated to its optimal working range from its storage range during the image capture mode. A separate dynamic control loop is also used to maintain the optimal temperature for the satellite's batteries as per the mode of operation. Redundancy has been established using a mechanical thermostat based control loop in addition to the already planned dynamic control loop. This ensures the protection of the components during the emergency modes.

METHODOLOGY



CONSTRAINTS

Battery: Panasonic NCR18650B

Storage: -20°C to 50°C **Charging:** 10°C to 45°C

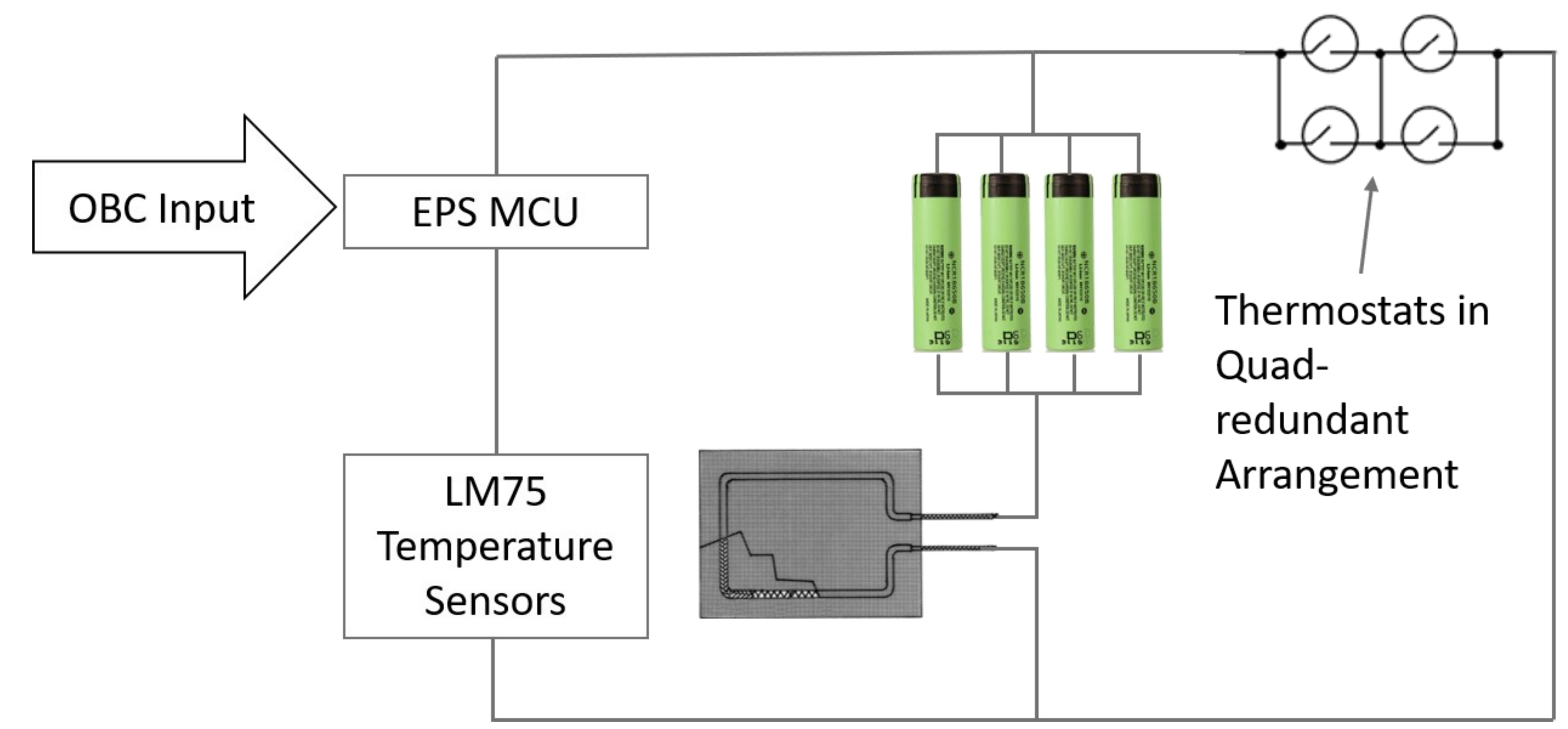
Payload: Ximea MQ022RG-CM

Storage: -25°C to 60°C **Optimal Operation:** 10°C to 25°C **Operation:** 0°C to 50°C

Preliminary Thermal Analysis

Worst Cold Case: -7.4°C **Worst Hot Case:** 68.7°C

SYSTEM CONFIGURATION



CONSIDERATIONS FOR MODES OF THE SATELLITE

Critically Low Battery State of Charge

In this mode, the components of the satellite would be switched off in a pre-decided order. EPS MCU would be the last component to switch off in this mode, hence heating can continue. The battery would be maintained in its safe storage range of 0°C to 50°C with the safe temperature critically reduced. Since the worst cold case of the satellite with no heater arrangement predicts a temperature that is 17.6°C more than the lower limit of payload storage, the payload heating circuit will be switched off in this mode.

Battery Low Temperature

The battery must be maintained in its safe storage temperature. The thermostats would be calibrated such that they automatically engage to heat the battery when it falls under consideration for this mode. The payload heating circuit would be switched off to save power. The interrupt from the temperature sensors will be increased for the dynamic control system.

Payload Low Temperature

This mode was initially studied as a possibility. However, as per the thermal simulation results, the payload will never fall below its safe storage temperature range. Hence, this mode will not be of importance in de-

Payload execution

In this mode, the component of major concern is the payload. The imager must be maintained in its optimal operating range throughout, which is between +10°C and +25°C. The satellite will not be in eclipse during image capture; hence, the battery must be maintained in its charging range i.e. +10°C to +45°C. The payload must be ready for image capture before the mode starts and hence, similar constraints also must be applied to the mode preceding it, which is the *Payload Pointing mode.*

Other Modes of the satellite

The control system also needs to be calibrated for other operating modes of the satellite. In all modes, using the dynamic control loop would save power. This is because of the temperature values to which the thermostats have been calibrated. The fast cycling of thermostats increases the chances of their failure and hence they have been calibrated accordingly. The dynamic loop will be calibrated to prevent the thermostats from engaging unless necessary.

CONCLUSION: SAFE & THRESHOLD TEMPERATURES

Mode \ Variable	Payload Threshold Temperature	Payload Safe Temperature	Battery Threshold Temperature	Battery Safe Temperature
Critically Low Battery SoC	--	--	5°C	15°C
Battery Low Temperature	--	--	10°C	30°C
Payload Low Temperature	--	--	--	--
Payload Execution	15°C	20°C	15°C	30°C
Payload Pointing	15°C	20°C	15°C	30°C
Other Modes	10°C	30°C	10°C	30°C

ADVANTAGES:

- Tailored operation constraints for modes will optimize all the involved factors
- Increased power saving due to dynamic control of the heaters
- Increased redundancy due to secondary mechanical control loop
- Thermostat based control loop removes the reliance of the heater arrangement on the electronic systems

DISADVANTAGES:

- The battery box will require more space to accommodate more components
- Accurate onboard calculations are required for dynamic power supply to the heaters
- Additional components increase the cost of the system

TEAM ANANT

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