The Response of Fuzzy Electronics to Ionizing Radiation

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Extended Abstract

Small satellites such as CubeSats operate under environmental constraints that are outside of typical commercial specifications. Such constraints include the ability to operate over an extended temperature range and during exposure to ionizing radiation. Nevertheless, commercial technologies are being implemented in CubeSat spacecraft because of the low-cost, low-power, and space savings requirements often achievable with advanced microelectronics [1]. Due to flexibility and the ability to handle uncertainty, fuzzy logic is viable for satellite control while meeting the strict design requirements of a CubeSat. This work evaluates the response of fuzzy control logic to ionizing radiation and compares the response to that of conventional systems.

Fuzzy logic operates on multiple truth values which vary within the range of 0 and 1, as opposed to Boolean logic's precise, two-variable system. Fuzzy systems utilize "if-then" statements, known as membership functions. These allow for terms such as "moderately" or "slightly," to be utilized, permitting flexibility within the system. As such, fuzzy logic shows promise in robotics and mechanical control systems due to the ability to handle uncertainty and non-linearity. Thus, fuzzy logic electronics are a candidate for small satellite control mechanisms, creating the potential for radiation hardened control systems that take advantage of the low-power and space savings achievable by modern electronics technologies.

Ionizing radiation causes a plethora of issues in electronics. Dominant effeczts include is total-ionizing dose (TID) and single-event effects (SEE). TID results in the accumulation of charge in the oxides present throughout integrated circuits, altering the device and circuit parameters. SEEs generally result in erroneous transient behavior following the interaction of single ionizing particles with semiconductors.

Little is known about the response of fuzzy logic systems to such effects. This work aims to evaluate the effects of TID and SEE on a fuzzy logic small satellite attitude controller, describe the mechanisms of vulnerability, and compares the response to standard controller designs. Modeling and simulations are used to compare attitude controllers designed with two approaches: a fuzzy control system and a PID control system. Preliminary evidence indicates that fuzzy controllers are more efficient than PID controllers, reducing the response time and overshoot while improving stability, and potentially reducing the size and weight requirements [2]. Furthermore, simulations show that fuzzy logic is more robust to SEE than standard control algorithms [3]. Future work involves measurement of the TID and SEE responses in reaction wheel attitude controllers designed with fuzzy and PID algorithms.

References

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