MASTERBOND®
CASE STUDY

EP42HT-2AO-1 Black Open-Source Space-Tolerant Electromechanical Prototyping System

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EP42HT-2AO-1 Black: Open-Source Space-Tolerant Electromechanical Prototyping System

In recent decades, there has been an explosion in open-source hardware and software prototyping solutions for inventors, engineers, and product designers. Ushered in by Arduino in 2007 and Raspberry Pi in 2012, these open-source systems consist of single-board microprocessors and microcontrollers that can be utilized to create a wide variety of digital devices. Their versatility and availability now make it possible to rapidly design and construct a wide variety of prototype devices. With the rise of private companies like Space-X and Blue Origin, there has been renewed interest, investment, and innovations in space exploration. At the intersection of these two developments, the company Solar System Express sought to provide a new entry to the field of open-source hardware and software prototyping solutions with the advent of their space-tolerant, GDB E-Series. To help achieve robustness in the harsh atmosphere of space, Master Bond EP42HT-2AO-1 Black was utilized in the device's construction. Master Bond EP42HT-2AO-1 Black is a two-part, room temperature curing epoxy system that is compliant with NASA low outgassing standards, is thermally conductive to allow for heat dissipation, and it is serviceable over a wide temperature range from cryogenic temperatures to +400°F (+204°C).

Application

Solar System Express sought to develop and deliver to market the first space-tolerant, open-source hardware and software prototyping solution with their Gravity Development Board (GDB) E-Series line.[1] The goal of the project was to enable inventors, engineers, and small technology companies to readily create and provide novel solutions for use in space-based explorations. The device was developed to handle a wide array of functionality to include control of sensors, high current motors, and lighting. Compared to a terrestrial environment, an electronic device capable of reliably operating in a space-based environment requires special material and engineering controls. The vacuum environment of space is capable of deleteriously volatilizing migratable compounds and solvents present within materials of construction to include the sealants and encapsulants used in microelectronic components. Other factors include high g-load (acceleration) upon delivery to orbit, high levels of ionizable radiation, and an ability to tolerate wide temperature swings. In addition to space-tolerance, the GDB E-Series was also designed to be capable of handling desert, radiation spill/nuclear accident, high pressure environments, burning buildings and other extremely demanding applications.

Key Parameters and Requirements

Engineering required careful selection of the materials of construction that would enable robust operation, reliability, and longevity of the device—to include a suitable epoxy system capable of bonding, sealing, encapsulating or potting any required subcomponents for the rigorous specifications required. Relevant to sealant selection are temperature range/serviceability, modulus, thermal characteristics, and electrical non-conductivity.

Without the atmosphere of earth, objects in space will see severe temperature cycling due to the cyclical nature of solar exposure and a lack of protective/absorptive atmospheric gases. A sealant with a high glass transition temperature, Tg, is critical to assuring strong bonds at high temperatures; however, the modulus of the adhesive must be compliant enough at very low temperatures such that it does not become exceedingly brittle and result in a bond failure. Further, the coefficient of thermal expansion, CTE, must be carefully controlled relative to the substrates that are bonded. During thermal cycling, differential thermal expansion between different materials may result in the accumulation of stress that leads to die or board fracture or otherwise result in bond failure. Generally organic polymers are not very thermally conductive; the inclusion of thermally conductive filler materials to the sealant formulation is critical for dissipating and transferring the heat that builds up during operation. As with any electronics application, the sealant itself must be electrically non-conductive to avoid any short-circuiting. Unlike terrestrial environments, space-based devices must also comply with NASA's low outgassing standards; compliance with this standard assures that the cured sealant minimally outgasses volatile compounds when exposed to high vacuum conditions. The outgassing of even a small quantity of components from within the adhesive system can lead to deposition of the volatilized materials upon sensitive components such as lenses, junctions or mirrors leading to poor device function or premature failure. Due to the exceedingly high costs of objects introduced into orbit, longevity in the harsh environment of space is critical to mission success.

Master Bond EP42HT-2AO-1 Black is specially formulated for use in space-based applications providing compliance with NASA low outgassing standards and possessing a wide temperature serviceability covering cryogenic temperatures of 4K all the way up to +400°F (+204°C). The addition of selected mineral fillers enables it to provide high thermal conductivity aiding heat dissipation while maintaining a high degree of electrical non-conductivity. It is a versatile epoxy system suitable for potting, encapsulation, sealing, coating, and bonding. In addition, EP42HT-2AO-1 Black provides convenient viscosity and handling characteristics aiding device fabrication while providing minimal shrinkage upon cure. For the Solar System Express application, Master Bond EP42HT-2AO-1 Black was used to mount the GDB's crystal to the printed circuit board (PCB).

Results

Solar System Express exposed its devices to many rigorous tests and qualifications. As all their PCB footprints for crystals 3.579 to 30 MHz are the same, this enables GDB overclocking with their fastest stable clock speed of a particular architecture achieving 128 MHz.[1] Thermal vacuum testing was successful achieving a rating of $1x10^{-5}$ ATM and with a temperature range of -40 to 140°F (-40 to 60°C). Regarding radiation resistance, the devices include radiation shielding and are expected to handle the 100 rad/year exposure levels that would be expected in orbital environments. The company continues to develop their offerings with a goal to further increase the device capabilities in extreme environmental conditions.

References

[1] GDB E-Series Datasheet. *Space Tolerant Open-Source Electromechanical Prototyping System*. Solar System Express. URL: http://solarsystemexpress.weebly.com/uploads/5/0/6/0/5060129/gdb_e-series__datasheet__rev_0.9.1.1.pdf Accessed: March 10, 2022.