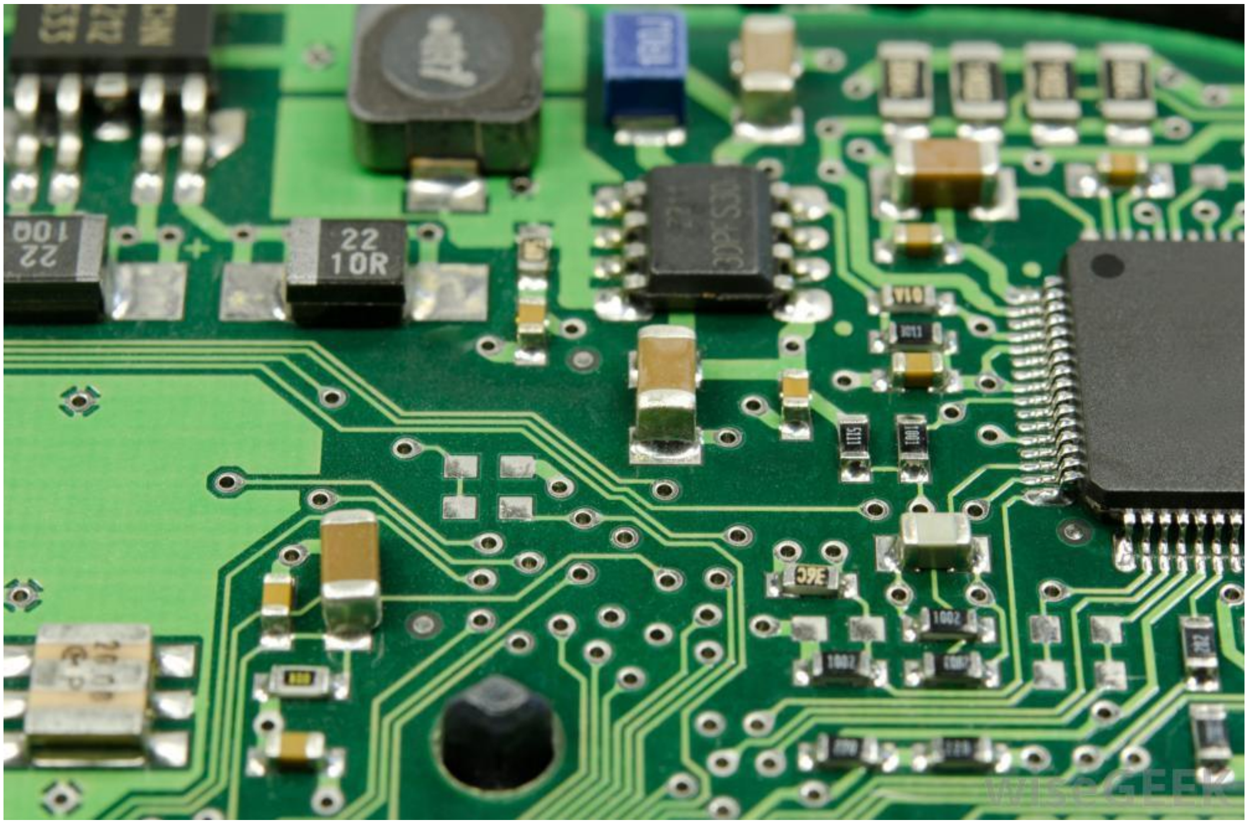


Component Reliability in Liquid Cooled Applications

Assessing the operation of electronic components and SD cards in Opticool Fluid over time.

Introduction

Contemporary electronic devices and computing platforms are operated in a number of conditions and environments never considered just a few short years ago. Simultaneously, the demand for increased power and miniaturization has impacted their use and application in these new settings as well. Considerations such as overheating, corrosion, and reliability also must be factored in when developing modern equipment and technologies. Liquid immersion cooling is one option that may be considered when seeking out new ways to overcome engineering challenges such as increased power densities and advance power management requirements.

When evaluating liquid immersion cooling for electronics-related applications, corrosion is often a concern with regards to long-term reliability of components and overall operation. The degree of corrosion damage is dependent upon a number of factors such as the type of immersion fluid chosen, equipment exposure time, operating temperature, and the introduction of contaminants/moisture, to name a few.

In order to better understand the role that these factors might play in electronics immersion cooling, a series of experiments have been designed to better understand how overall equipment operation is impacted in varying applications. For instance, a previous test was designed to demonstrate how liquid immersion cooling is used to mitigate overheating experienced during processor overclocking [1]. This paper is a continuation of these experiments and was conducted to evaluate any long-term effects on electronics components and secure digital cards (SD cards) when continually immersed in a controlled Opticool Fluid environment.

Device Reliability

As increased processing power and component miniaturization continues to evolve, thermal reliability and environmental factors will play an increasingly important role in future development efforts. Temperature is a fundamental aspect of systems design due to its' direct relation with component availability whereas power and operation are related to system efficiency. When discussing electronic components, the failure rate λ is commonly defined as the number of components failing per unit time [2]. Thus, component thermal reliability with a constant failure rate is expressed as [3]:

$$R(t) = \exp(-\lambda t)$$

A temperature-related reliability model based on the mean time to failure (MTTF) for processors has also been proposed where constant λ is as follows [4]:

$$MTTF = \int_o^\infty R(t)dt = \int_o^\infty \exp(-\lambda t)\,dt = \frac{1}{\lambda}$$

The model above is based on 5 component failure rates including the number of failures per million hours (C_1 *and* C_2), temperature factors (π_t), quality factor (π_Q), learning factor (π_L), and environmental factor (π_E), thus:

$$\lambda = (C_1\,\pi_t + C_2\,\pi_E)\pi_Q\pi_L$$

As shown in the model above, temperature and environment each affect the overall reliability of microprocessors, with thermal behavior often influenced by the type of application being run.

Equipment Configuration and Setup

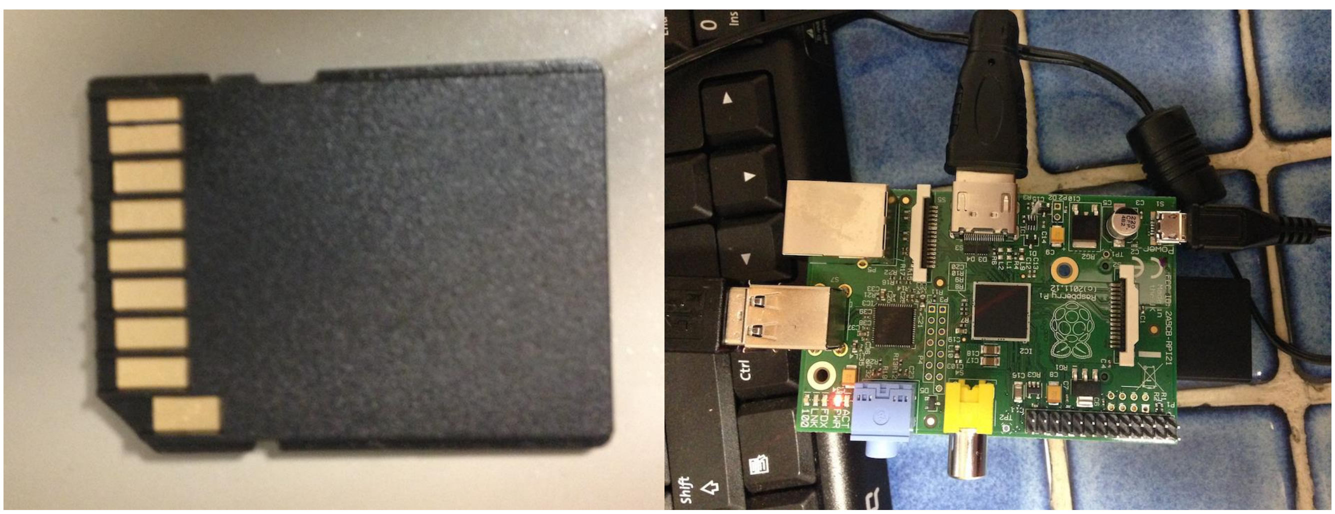
The Raspberry Pi computing device was selected for this test due to its condensed size and overclocking capability. The Raspberry Pi device is representative of ways that smaller component sizes are leading to more powerful computing. For example, the device has been used for media streaming, home automation, and robotic applications, to name a few [5]. Both the Raspberry Pi and SD card were tested and confirmed to be operating properly prior to the start of this evaluation.
The Raspberry Pi unit and SD card were next immersed in Opticool Fluid coolant as shown in Figure 1.

5V was applied to power the device and a fluid temperature of 20.3°C was maintained for the duration of the experiment. The fluid was circulated using a 75 RPM motor.

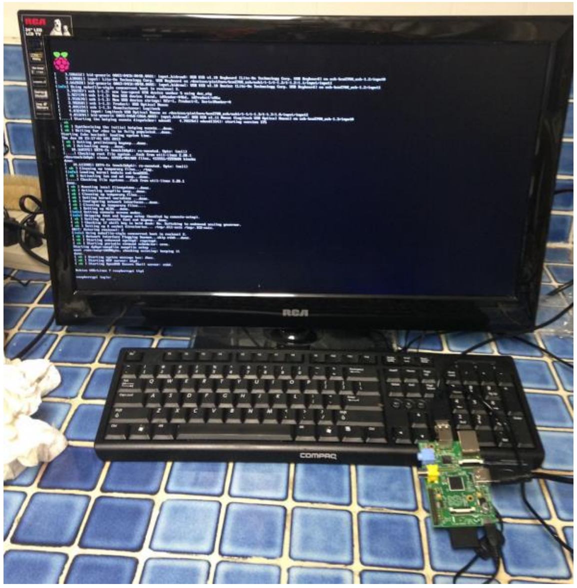
Results

The test was conducted over a 6-month period. During this timeframe, the temperature of the fluid was monitored and maintained continuously. No changes were recorded during this time period. 5V was continuously supplied to power the device during the same period.

At the 6-month mark, the Raspberry Pi device and SD card were removed for inspection and testing. Neither the Raspberry Pi nor the SD card displayed any visual indication of surface corrosion as shown in Figure 2.



In addition to visual inspection, the functionality of both the Raspberry Pi and SD card was tested outside the fluid. Test results indicated that neither the Raspberry Pi device or SD card were affected by corrosion during the testing period. The devices continued to boot up and operate properly as shown in Figure 3. This indicates that Opticool Fluid has no adverse affects on various component types or SD cards over time.



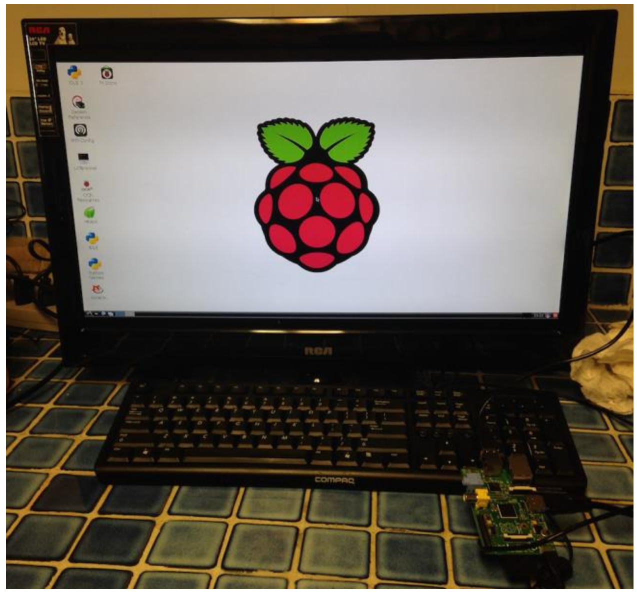


Figure 3: Successful post-immersion operating system load.

Conclusion

As devices continue to shrink in size while increasing in power, performance improvements will continue to be plagued by increased power and cooling requirements. Furthermore, high temperatures negatively affect component reliability dependent on effective design and thermal management techniques. The results obtained during this experiment demonstrated that the integrity of various types of electronic components and devices are maintained over time in Opticool Fluid. This demonstrates a viable thermal management and design option for application developers and engineers.

Reference

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