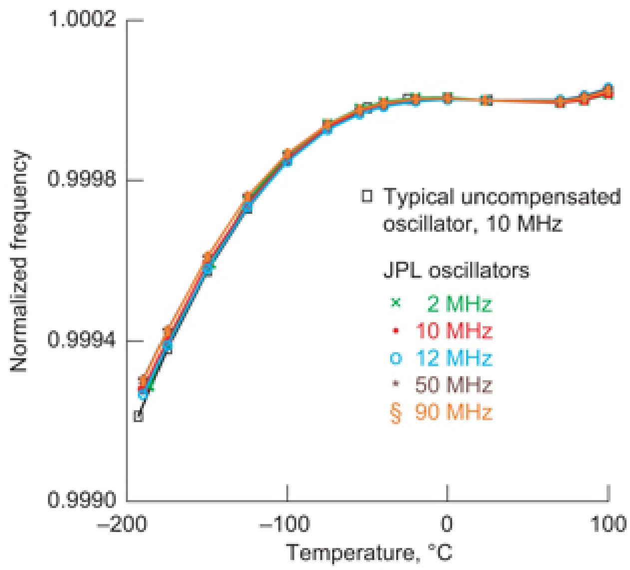
Reliability of Electronics for Cryogenic Space Applications Being Assessed

Many future NASA missions will require electronic parts and circuits that can operate reliably and efficiently in extreme temperature environments below typical device specification temperatures. These missions include the Mars Exploration Laboratory, the James Webb Space Telescope, the Europa Orbiter, surface rovers, and deep-space probes. In addition to NASA, the aerospace and commercial sectors require cryogenic electronics in applications that include advanced satellites, military hardware, medical instrumentation, magnetic levitation, superconducting energy management and distribution, particle confinement and acceleration, and arctic missions. Besides surviving hostile space environments, electronics capable of low-temperature operation would enhance circuit performance, improve system reliability, extend lifetime, and reduce development and launch costs. In addition, cryogenic electronics are expected to result in more efficient systems than those at room temperature.

Presently, electronic parts suppliers rate their commercial-off-the-shelf components for operation between 0 and 70 °C. These parts have limitations in extended temperature ranges because of the materials used, device design and packaging, and manufacturing processes. Military-grade devices are rated at -55 to 125 °C, and use different processes. Limited information is available on the performance of components and circuits outside of these temperature ranges. In addition, little is known about the effects of the thermal cycling that is typical of most space missions. Understanding the effects of extreme temperatures on electronics and determining their performance reliability are critical elements for aiding mission planners in the design of spacecraft power systems, as well as in establishing associated risk factors.

There are ongoing efforts at the NASA Glenn Research Center to establish a database on the reliability of electronic devices under extreme low-temperature operation for space applications. These efforts are performed under NASA’s Low-Temperature Electronics Program with emphasis on device and circuit characterization at cryogenic temperatures and under long-term, wide-temperature thermal cycling. The results of these investigations will be used to establish safe operating areas and to identify degradation mechanisms and failure modes. This body of knowledge will be disseminated to mission planners and system designers in order to optimize design and mitigate risks. Electronics investigated in this work include passive and active components, digital and analog transducers, direct-current to direct-current converters, sensors, logic and control circuits, operational amplifiers, and semiconductor switches. The graph, for example, shows the normalized output frequency of five programmable oscillators along with that of a typical uncompensated 10-MHz oscillator as a function of temperature between 100 and -195 °C. It can be clearly seen that the curves for the five Jet Propulsion Laboratory (JPL) programmable oscillators were virtually identical to each other and to that of the crystal oscillator, and that the frequency of all the devices began to drop as the temperature approached around -40 °C. This decrease in frequency became steeper as temperature was reduced further.



Normalized output frequency of six oscillators versus temperature. Frequency normalized Long description of figure. Normalized output frequency of six oscillators (typical uncompensated 10-MHz oscillator along with 2-, 10-, 12-, 50-, and 90-MHz JPL oscillators) as a function of temperature between 100 to −195 °C. The graph shows that the frequency of all oscillators begins to drop at temperatures of −40 °C and below.*to frequency at 23 °C.*

These research efforts are being performed by support from the NASA Electronic Parts and Packaging (NEPP) Program and through collaboration with other Government agencies, industrial and aerospace companies, and academia. The program supports missions as well as technology development efforts at the NASA Goddard Space Flight Center, the NASA Langley Research Center, and JPL.

Find out more about this research at http://www.grc.nasa.gov/WWW/epbranch/ephome.htm

Glenn contact: Richard L. Patterson, 216-433-8166, Richard.L.Patterson@nasa.gov
QSS Group, Inc., contact: Ahmad Hammoud, 216-433-8511, Ahmad.Hammoud@grc.nasa.gov
Authors: Richard L. Patterson and Ahmad Hammoud

Headquarters program office: OSS
Programs/Projects: NEPP, NEPAG, JWST, Mars 07, JIMO, Europa Lander