Investigation of Ge Transistors for Cryogenic Power Applications

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Cryogenic power electronics has potential applications in aerospace, industrial and commercial areas. For example, there is interest by NASA in power electronics that can operate down to temperatures of approximately 30-40 K for spacecraft power management [1-3] and for drivers for actuators and motors for spacecraft [4]. Industrial/ commercial applications include those using cryogenics and possibly superconductivity, such as power transmission, distribution, and storage, power circuitry for motors and generators, and medical equipment.

In view of these applications, we have begun investigating diodes and transistors for operation down to 30 K and preferably down to 4 K, directed toward developing medium-to-high power devices. Our success in operating low-power Ge JFETs down to 4 K [5-6] has encouraged us to consider Ge devices for these deep cryogenic power applications as well.

We have found very little existing data on Ge diodes and transistors at cryogenic temperatures. Consequently, we have begun characterizing available commercial Ge devices (diodes and bipolar junction transistors) at cryogenic temperatures.

We find that Ge diodes retain useable characteristics down to 4 K. We are extending our characterization of field-effect transistors to higher power. In addition, we are investigating bipolar junction transistors (BJTs), since modern power devices, such as the MCT (MOS-controlled thyristor) and the IGFET (insulated-gate bipolar transistor), often combine both bipolar and field-effect structures. We find that certain types of BJTs work down to deep cryogenic temperatures. Initial results from two low-power Ge BJTs are shown in Figure 1, spanning the temperature range 300 K to 20 K, demonstrating their potential to retain a useable gain down to below 30 K, as required for our intended applications.

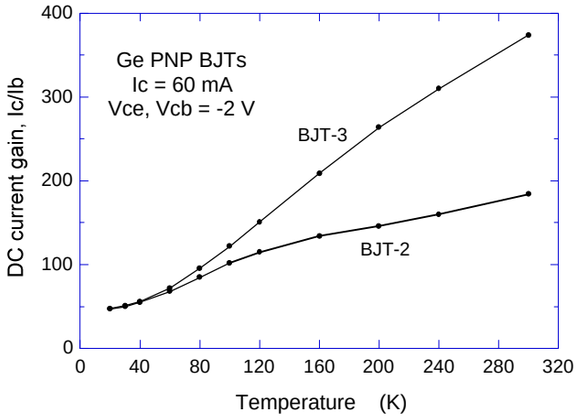

Figure 1 – DC current gain of two Ge PNP bipolar junction transistors down to cryogenic temperatures, illustrating retention of useable gain down to approximately 20 K.

[1] R. L. Patterson, A. Hammoud, J. E. Dickman, S. S. Gerber and E. Overton, “The low temperature electronics program at NASA Lewis Research Center,” *NASA/JPL Conf. on Electronics for Extreme Environments*, Pasadena, California, Feb. 1999.

[2] R. L. Patterson, A. Hammoud, J. E. Dickman, S. S. Gerber and E. Overton, “Development of electronics for low temperature space missions,” *Proc. 4th European Workshop on Low Temperature Electronics (WOLTE 4)*, Noordwijk, The Netherlands, 21-23 June 2000, ESA publication WPP-171, pp. 115-119.

[3] http://www.grc.nasa.gov/WWW/RT1996/5000/5480di.htm “Cryogenic electronics in support of deep-space missions.”

[4] http://www.ngst.nasa.gov/Hardware/text/actuator.html and http://ngst.gsfc.nasa.gov/Hardware/text/actuator_reqs.html

[5] R. R. Ward et al., "Development of cryogenic Ge JFETs - II," presented at the *Electrochemical Society Fifth International Symposium on Low Temperature Electronics*, 21 October 1999 in Honolulu, Hawaii, U.S.A.

[6] R. R. Ward et al., "Development of cryogenic Ge JFETs - III," *Proc. 4th European Workshop on Low Temperature Electronics (WOLTE 4)*, Noordwijk, The Netherlands, 21-23 June 2000, ESA publication WPP-171, pp. 105-111.

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