

NASA Electronic Parts and Packaging Program

Performance of an SOI Boot-Strapped Full-Bridge MOSFET Driver, Type CHT-FBDR, under Extreme Temperatures

Richard Patterson, NASA Glenn Research Center
Ahmad Hammoud, ASRC Corporation / NASA GRC

Scope

Electronic systems designed for use in deep space and planetary exploration missions are expected to encounter extreme temperatures and wide thermal swings. Silicon-based devices are limited in their wide-temperature capability and usually require extra measures, such as cooling or heating mechanisms, to provide adequate ambient temperature for proper operation. Silicon-On-Insulator (SOI) technology, on the other hand, lately has been gaining wide spread use in applications where high temperatures are encountered. Due to their inherent design, SOI-based integrated circuit chips are able to operate at temperatures higher than those of the silicon devices by virtue of reducing leakage currents, eliminating parasitic junctions, and limiting internal heating. In addition, SOI devices provide faster switching, consume less power, and offer improved radiation-tolerance. Very little data, however, exist on the performance of such devices and circuits under cryogenic temperatures. In this work, the performance of an SOI boot-strapped, full-bridge driver integrated circuit was evaluated under extreme temperatures and thermal cycling. The investigations were carried out to establish a baseline on the functionality and to determine suitability of this device for use in space exploration missions under extreme temperature conditions.

Test Procedure

The device investigated in this work comprised of a high temperature, boot-strapped full-bridge driver that was introduced recently by CISSOID Corporation. The CHT-FBDR device is designed for driving n-channel, metal-oxide semiconductor field-effect transistors (MOSFETs) in a full-bridge configuration [1]. It has an internal clock of 200 kHz, and features gate high-side voltages up to 60 V. An external clock provided 30 kHz logic signals to control the chip. Each of the four outputs of the chip fed a 14 pF load (scope lead). Figure 1 shows the SOI chip mounted on a high-temperature polyimide board. The passive elements, which consisted mostly of NP0 ceramic capacitors, were mounted on the other side of the board as shown in Figure 2. Some of the manufacturer's specifications for this SOI chip are shown in Table I [1]. High temperature Teflon-insulated wires were used along with 300 °C special solder. Operation of the chip was investigated as a function of temperature between -190 °C and +225 °C. Performance characterization of the SOI driver chip was obtained in terms of its four output signals, output signal rise and fall times, and supply current (I_s) at specific test temperatures. These temperatures were +25, +50, +100, +150, +175, +200, +225, 0, -50, -100, -150,

-175, and -190 °C. A LeCroy LT374 Digital Scope was used to measure the switching frequency and to capture the output waveforms. A temperature rate of change of 10 °C per minute was used, and a soak time of at least 20 minutes was allowed at every test temperature. Restart capability at extreme temperatures, i.e. power switched on while the device was soaking at the test temperature of either +225 or -190 °C, was also investigated. In addition, the effects of thermal cycling under a wide temperature range on the operation of this driver chip were determined. The device was exposed to a total of 12 cycles between -190 °C and +225 °C at a temperature rate of 10 °C/minute. Following the thermal cycling, measurements were then performed at the test temperatures of +25, -190, and +225 °C.

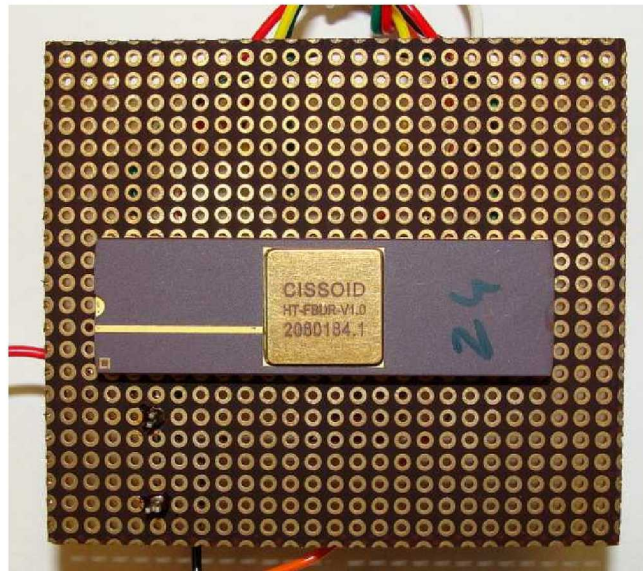


Figure 1. CISSOID CHT-FBDR device mounted on circuit board.

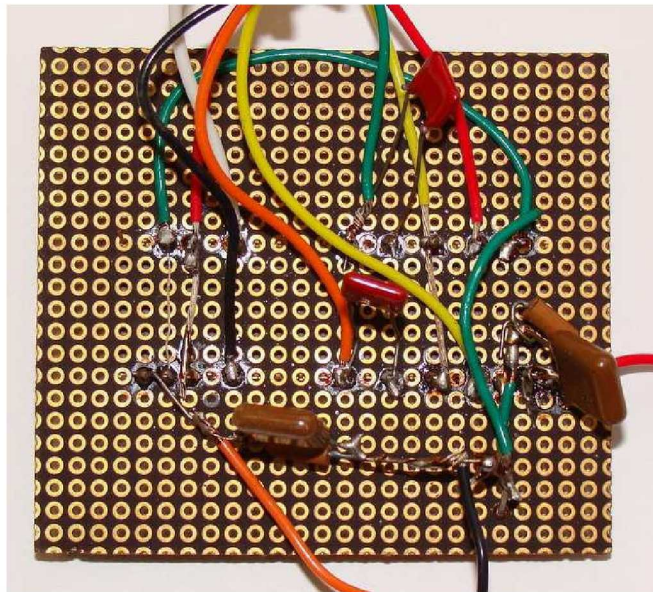


Figure 2. Passive components mounted on the other side of circuit board.

Table I. Specifications of CISSOID CHT-FBDR chip [1].

Parameter	Symbol	CHT-FBDR
Digital Supply Voltage (V)	V_{DD}	4.75 to 5.25
Analog Supply Voltage (V)	V_A	8 to 10
High-Side MOSFET Voltage (V)	V_{HV}	50
Internal Clock Frequency (kHz)	CK	200
High-Side Sink Current (mA)	$I_{o(sink)}$	20
Low-Side Sink Current (mA)	$I_{o(sink)}$	80
Operating Temperature (°C)	T(oper)	-50 to +225
Package		Ceramic DIL-40
Lot Number		CHT-FBDR-DIL40-T

Test Results

Temperature Effects

Waveforms of the CHT-FBDR driver output signals obtained at room temperature are shown in Figure 3. These waveforms were also obtained, as mentioned earlier, at the test temperatures of +50, +100, +150, +175, +200, +225, 0, -50, -100, -150, -175, and -190 °C. No major change or distortion was observed in the shape or magnitude of these waveforms as test temperature was changed throughout the range of -190 °C to +225 °C. For illustrative purposes, therefore, only those waveforms obtained at the extreme temperature, i.e. -190 °C and +225 °C, are also presented here as shown in Figures 4 and 5, respectively.

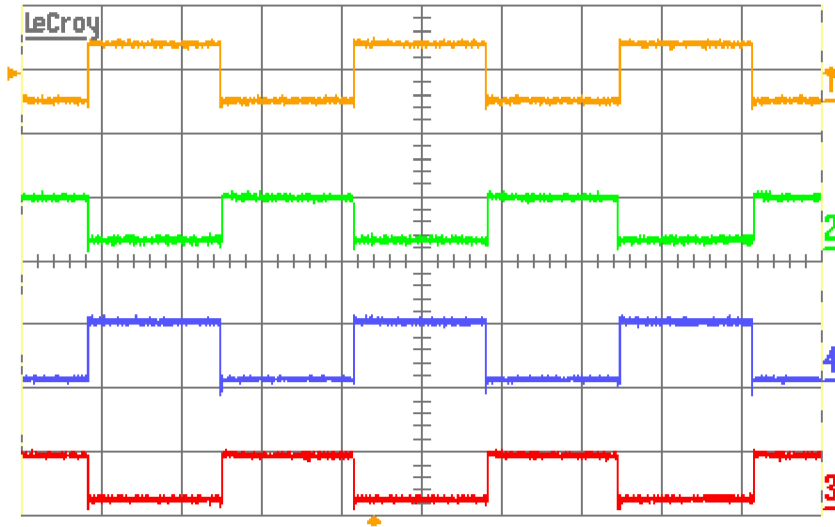


Figure 3. Waveforms of CHT-FBDR output signals at +25°C.
(Scale: Vertical 10 V/div; Horizontal 10 μs/div)

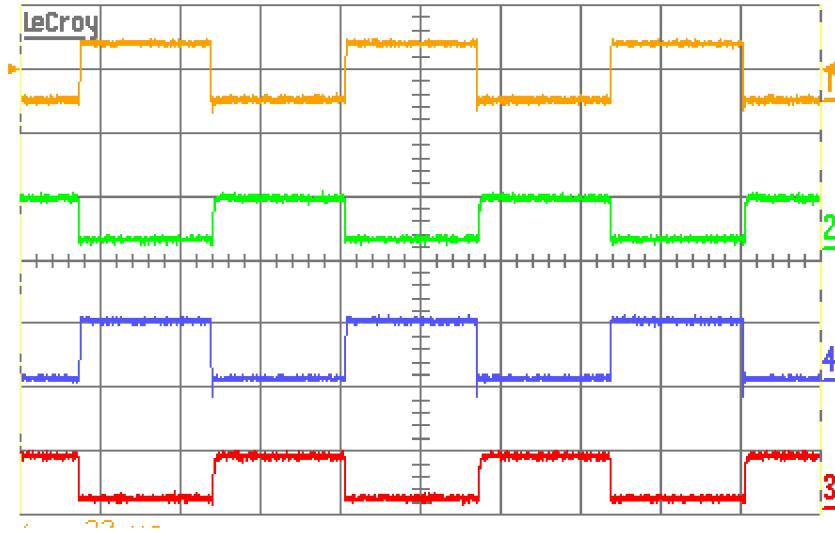


Figure 4. Waveforms of CHT-FBDR output signals at -190°C.
(Scale: Vertical 10 V/div; Horizontal 10 μs/div)

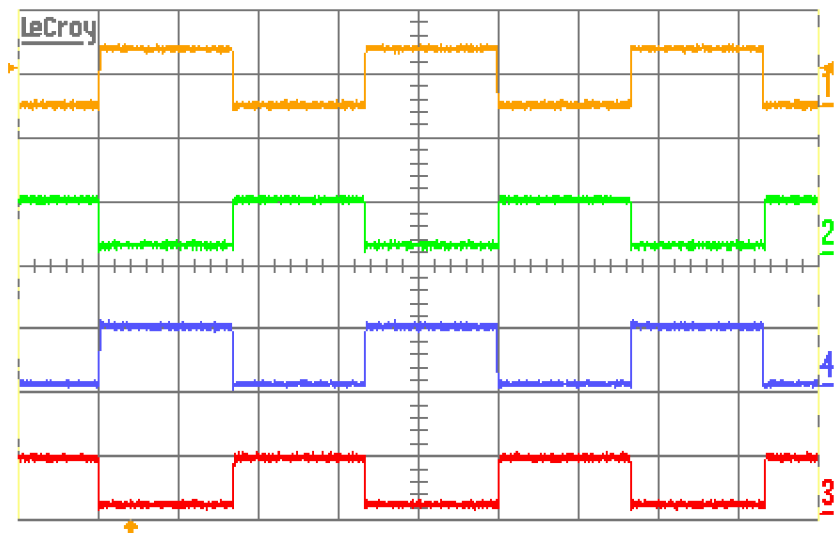


Figure 5. Waveforms of CHT-FBDR output signals at +225°C.
(Scale: Vertical 10 V/div; Horizontal 10 μs/div)

Figure 6 shows the rise and the fall times of one of the four output signals of the full-bridge driver as a function of temperature. In general, the fall time exhibited a gradual increase with temperature with the changes being more intense at the test temperature of +150 °C and higher. Unlike the fall time, the rise time of the output signal did not show consistent behavior with variation in temperature. As shown in Figure 6, the rise time experienced a trend similar to that of the fall time between -100 °C and +225 °C, however, the trend was reversed in the low temperature region between -100 °C and -190 °C. The input current to the bridge driver chip exhibited very slight increase as temperature increased from -190 °C to -50 °C; afterwards the current remained relatively flat as shown in Figure 7.

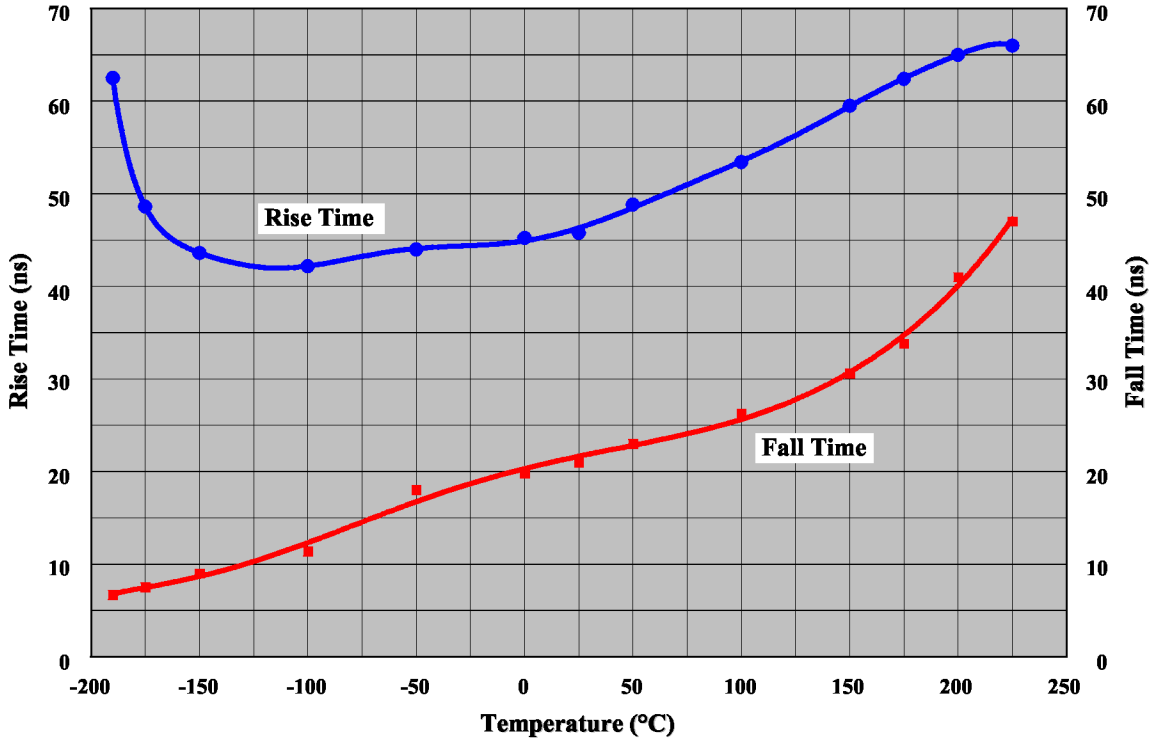


Figure 6. Rise and fall times of the CHT-FBDR as a function of temperature.

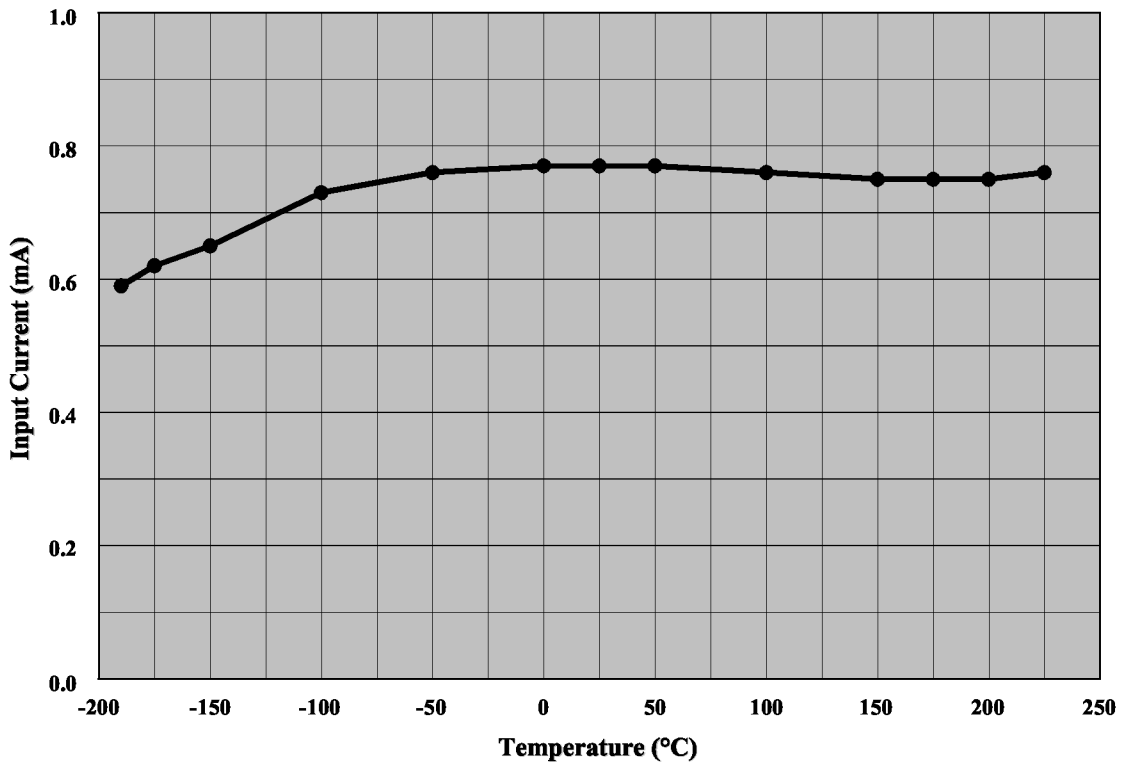


Figure 7. Supply current of the CHT-FBDR as a function of temperature.

Restart at Extreme Temperatures

Restart capability of the CISSOID CHT-FBDR chip at extreme temperatures was also investigated by allowing the device to soak for at least 20 minutes at each of the test temperatures of $-190\text{ }^{\circ}\text{C}$ and $+225\text{ }^{\circ}\text{C}$ without electrical bias. Power was then applied to the driver circuit, and measurements were taken on the output characteristics. The driver chip was able to successfully restart at both extreme temperatures and the results obtained were the same as those attained earlier for both temperatures.

Effects of Thermal Cycling

The effects of thermal cycling under a wide temperature range on the operation of the CISSOID CHT-FBDR driver IC chip were investigated by subjecting it to a total of 12 cycles between $-190\text{ }^{\circ}\text{C}$ and $+225\text{ }^{\circ}\text{C}$ at a temperature rate of $10\text{ }^{\circ}\text{C}/\text{minute}$. A dwell time of 20 minutes was applied at the extreme temperatures. Measurements of the investigated parameters were then taken as a function of temperature. A comparison of the waveforms of the driver output signals at the selected test temperatures of $+25$, -190 , and $+225\text{ }^{\circ}\text{C}$ for pre- and post-cycling conditions are shown in Figures 8, 9, and 10, respectively. It can be clearly seen that the post-cycling modulated outputs at any given test temperature were the same as those obtained prior to cycling. Similarly, no significant changes were registered between the pre- and post-cycling values of the output signal rise and fall times, its duty cycle, and the circuit's input current, as shown in Table II at the selected three test temperatures. Therefore, it can be concluded that the extreme temperature exposure and the thermal cycling did not induce much change in the behavior of this silicon-on-insulator full-bridge driver integrated circuit chip. This limited thermal cycling also appeared to have no effect on the structural integrity of this device as no structural deterioration or packaging damage was observed.

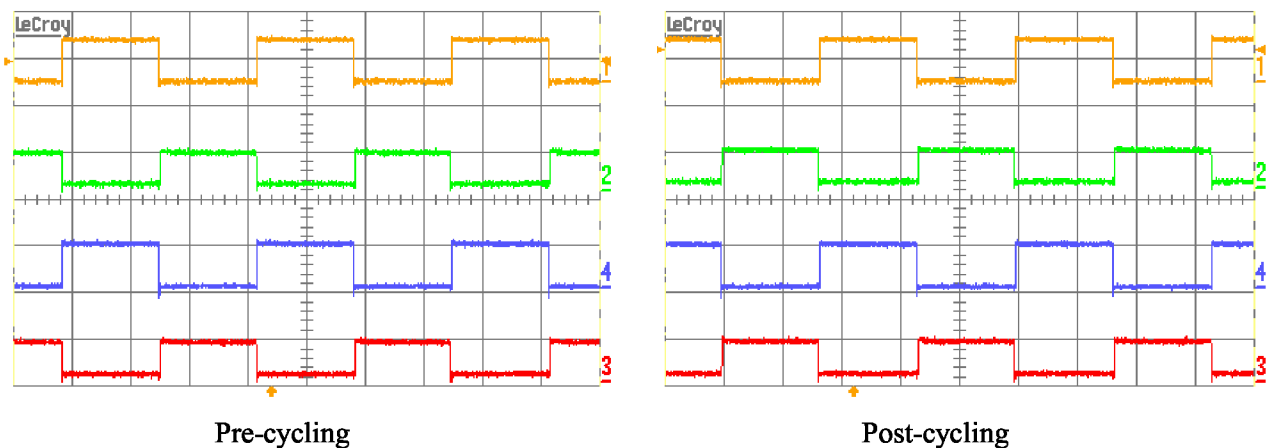


Figure 8. Pre- and post-cycling waveforms of CHT-FBDR output signals at $+25\text{ }^{\circ}\text{C}$.
(Scale: Vertical 10 V/div; Horizontal 10 $\mu\text{s}/\text{div}$)

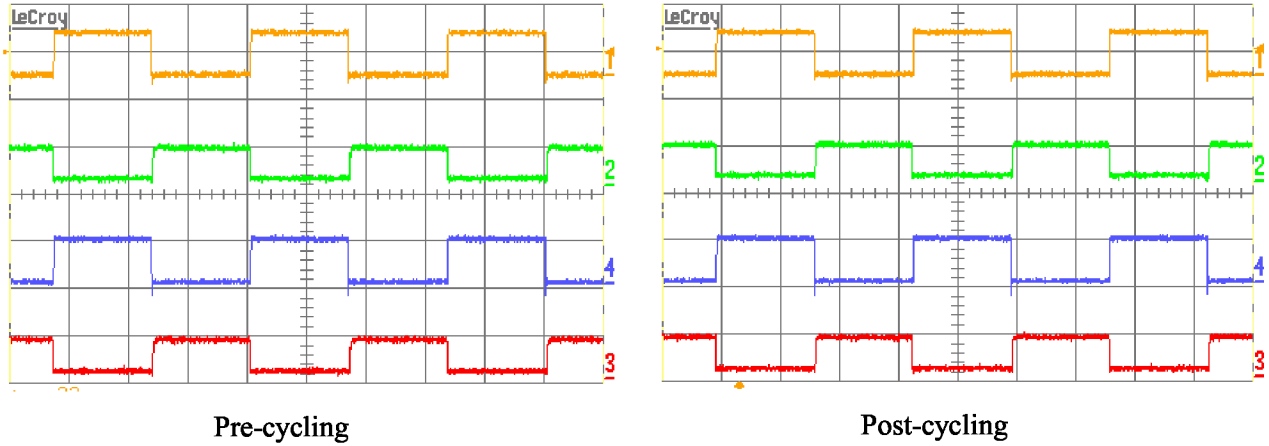


Figure 9. Pre- and post-cycling waveforms of CHT-FBDR output signals at -190°C .
 (Scale: Vertical 10 V/div; Horizontal 10 μs /div)

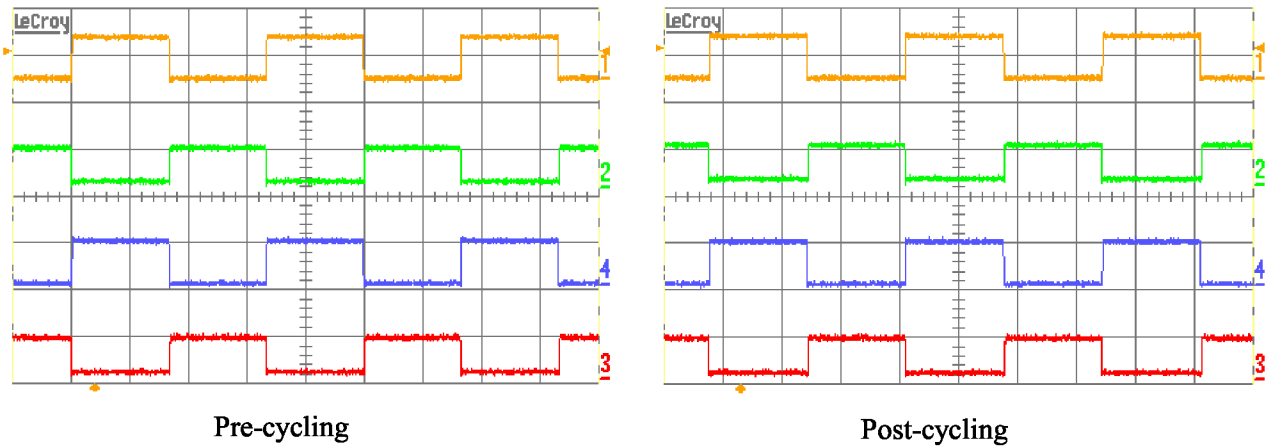


Figure 10. Pre- and post-cycling waveforms of CHT-FBDR output signals at $+225^{\circ}\text{C}$.
 (Scale: Vertical 10 V/div; Horizontal 10 μs /div)

Table II. Pre- & post-cycling values of rise and fall times, duty cycle, and input current.

Temp. ($^{\circ}\text{C}$)	Rise Time (ns)		Fall Time (ns)		Duty Cycle (%)		Input Current (mA)	
	Prior	Post	Prior	Post	Prior	Post	Prior	Post
+25	45.8	46.7	21.0	21.1	49.7	49.7	0.77	0.77
-190	62.5	62.0	6.7	7.1	49.6	49.6	0.59	0.59
+225	66.0	64.3	47.0	48.4	49.7	49.7	0.76	0.76

Conclusions

A new SOI (silicon-on-insulator) full-bridge MOSFET driver integrated circuit chip, a CISSOID type CHT-FBDR, was evaluated for operation between -190 °C and +225 °C. The effects of thermal cycling under a wide temperature range on the operation of this chip and extreme temperature restart capability were also investigated. The driver circuit was able to maintain good operation between -190 °C and +225 °C without undergoing any changes in its outputs and characteristics. The limited thermal cycling performed on the device had no effect on its performance, and the driver chip was able to successfully restart at each of the extreme temperatures of -190 °C and +225 °C. The ceramic packaging of this device was also not affected by the extreme temperature exposure. These preliminary results indicate that this SOI-based full-bridge driver integrated circuit could be potentially used in space exploration missions under extreme temperature environments. Further testing under long-term cycling is, however, required to fully establish the reliability of such devices and to determine their suitability for extended use in the harsh environments of space.

References

- [1]. CISSOID Corporation “CHT-FBDR High Temperature, Boot-strapped Full-Bridge MOSFET Driver” Data Sheet, Doc. DS-080271, V02.00, September 26, 2008. <http://www.CISSOID.com>

Acknowledgements

This work was performed at the NASA Glenn Research Center under GESS-2 Contract # NNC06BA07B. Funding was provided from the NASA Electronic Parts and Packaging (NEPP) Program Task “Reliability of SiGe, SOI, and Advanced Mixed Signal Devices for Cryogenic Power Electronics”.