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Evaluation of a High Temperature SOI Half-Bridge MOSFET Driver, Type CHT-HYPERION

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Scope

Silicon-On-Insulator (SOI) technology utilizes the addition of an insulation layer in its structure to reduce leakage currents and to minimize parasitic junctions. As a result, SOI-based devices exhibit reduced internal heating as compared to the conventional silicon devices, consume less power, and can withstand higher operating temperatures. In addition, SOI electronic integrated circuits display good tolerance to radiation by virtue of introducing barriers or lengthening the path for penetrating particles and/or providing a region for trapping incident ionization. The benefits of these parts make them suitable for use in deep space and planetary exploration missions where extreme temperatures and radiation are encountered. Although designed for high temperatures, very little data exist on the operation of SOI devices and circuits at cryogenic temperatures. In this work, the performance of a commercial-off-the-shelf (COTS) SOI half-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 an SOI high-temperature half-bridge driver that was introduced recently by CISSOID Corporation. The CHT-HYPERION device is a high-side and low-side driver for power N-channel, metal-oxide semiconductor field-effect transistors (MOSFETs) in DC-DC converters and electric motor control applications [1]. The manufacturer's preliminary data rate the device for operation between -55° C and +225 °C, and the floating high-side driver can sustain boost voltages up to 35 V. Some of the manufacturer's specifications for this SOI chip are shown in Table I [1].

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

Parameter	**Symbol**	**CHT-HYPERION**
Digital Supply Voltage (V)	V_{DD}	4.5 to 5.5
Input Current (mA)	I_{VDD}	3.45
Input Supply Voltage (V)	V_{IN}	3.5 to 30
Output Current (A)	I_O	> 1
Operating Temperature (°C)	T(oper)	-55 to +225
Package		Ceramic DIL-28
Lot Number		2090139.1

Figure 1 shows the SOI chip mounted on a high-temperature polyimide board along with the required passive elements that consisted mostly of NP0 ceramic capacitors and metal-film resistors. 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. An Agilent Function Generator, Model 33120A, was used to provide a 200 kHz square wave as the control signal for the PWM (pulse-width-modulation) input pin. Performance characterization of the SOI driver chip was obtained in terms of its high-side and low-side output signals, propagation delay times, and supply current at specific test temperatures. The outputs of the device were connected only to the oscilloscope. The propagation delay times included t_{pdl}, the transition delay between the PWM signal and the low-side driver output signal (LSDRV), and t_{pdh}, the transition delay between the high-side (HSDRV) signal and LSDRV; sometimes referred to as "dead time". The HSDRV output was configured to be in phase with the PWM logic signal. The test temperature points were -190, -175, -150, -100, -50, 0, +20, +50, +100, +150, +175, +200, and +225 °C. A LeCroy LT374 Digital Scope was used to measure the transition times 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 -190, +20, and +225 °C.

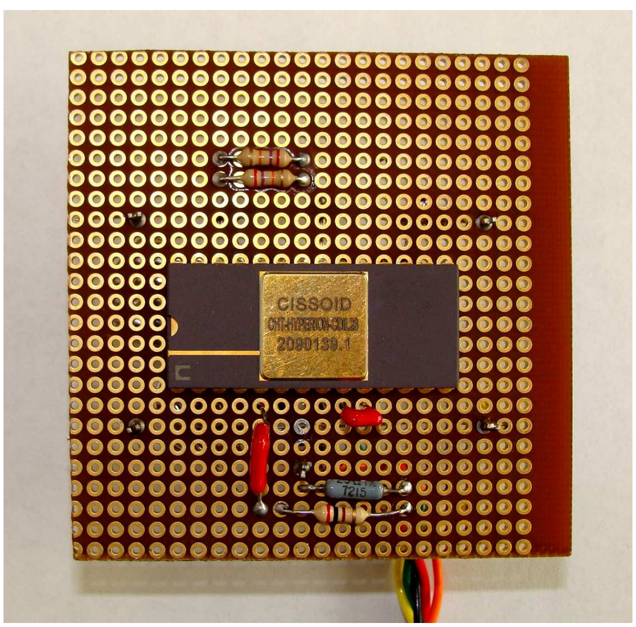


Figure 1. CHT-HYPERION half-bridge driver and passive parts mounted on test board.

Test Results

Temperature Effects

Waveforms of the CHT-HYPERION high-side driver (HSDRV) and the low-side driver (LSDRV) output signals along with the external PWM signal recorded at room temperature are shown in Figure 2. These waveforms were also obtained, as mentioned earlier, at the test temperatures of -190, -175, -150, -100, -50, 0, +20, +50, +100, +150, +175, +200, and +225 °C. No major change 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 3 and 4, respectively.

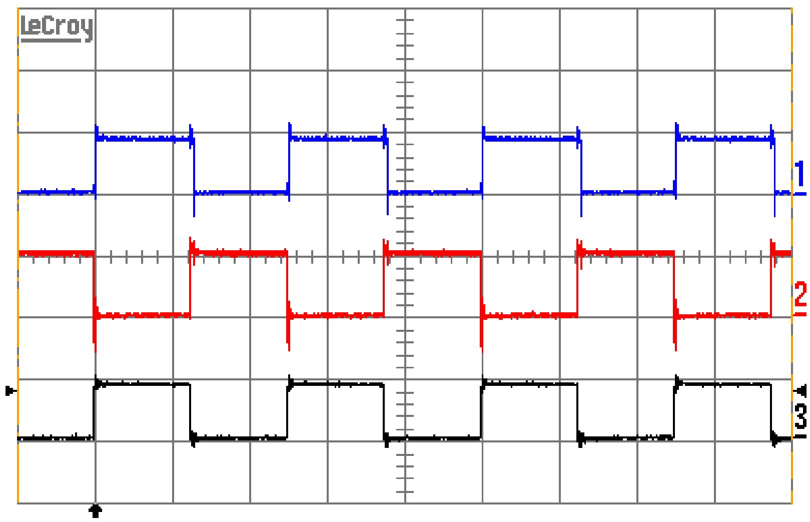


Figure 2. HSDRV (trace 1), LSDRV (trace 2), and PWM (trace 3) signals at +20°C.
(Scale: Vertical 5 V/div; Horizontal 2 μs/div)

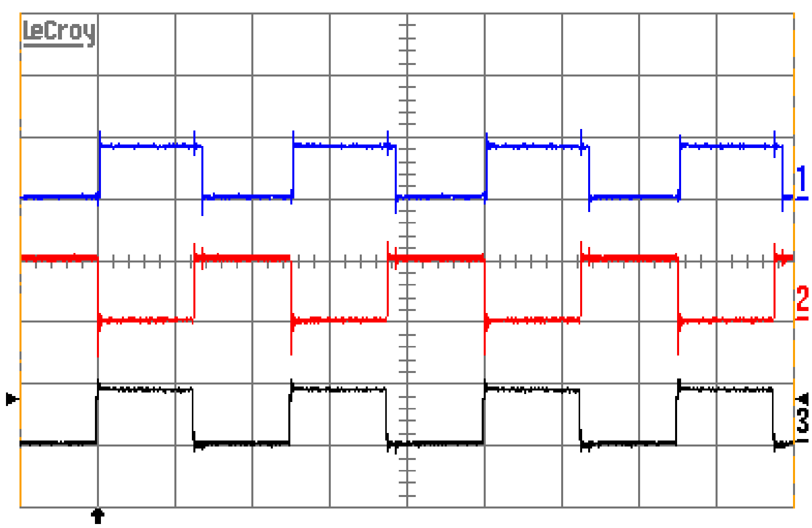


Figure 3. HSDRV (trace 1), LSDRV (trace 2), and PWM (trace 3) signals at -190°C.
(Scale: Vertical 5 V/div; Horizontal 2 μs/div)

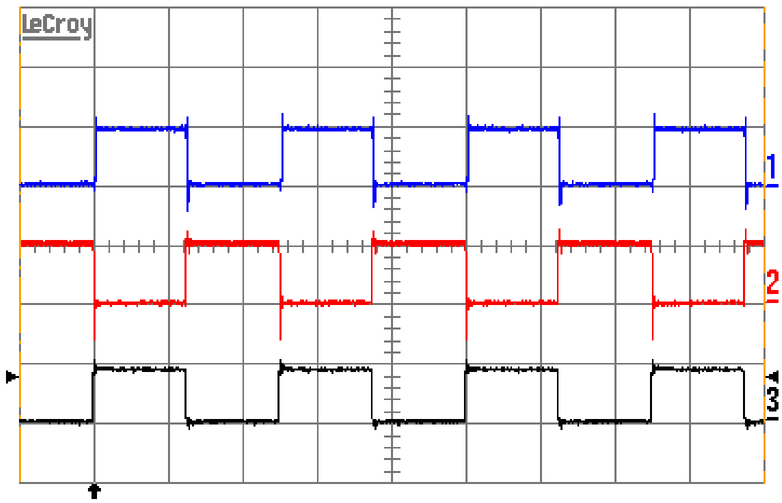


Figure 4. HSDRV (trace 1), LSDRV (trace 2), and PWM (trace 3) signals at +225°C.
(Scale: Vertical 5 V/div; Horizontal 2 μs/div)

Figure 5 shows the propagation delay time t_{pdl} between the PWM signal and the low-side driver output signal (LSDRV), and the transition delay t_{pdh} between the high-side (HSDRV) signal and LSDRV of the half-bridge driver as a function of temperature. It can be seen that while the delay time t_{pdl} decreased, almost linearly, with decreasing temperature, the transition delay between the high-side (HSDRV) signal and LSDRV, i.e. t_{pdh}, remained largely unaffected with temperature between - 100 °C and +225 °C. As the test temperature was further decreased below -100 °C, however, this transition delay time experienced noticeable increase with decreasing temperature; reaching a value of 80 ns at the cryogenic level of -190 °C as compared to that at room temperature of 52 ns. The impact of the changes in propagation delay times depends upon the timing requirements for the load being driven.

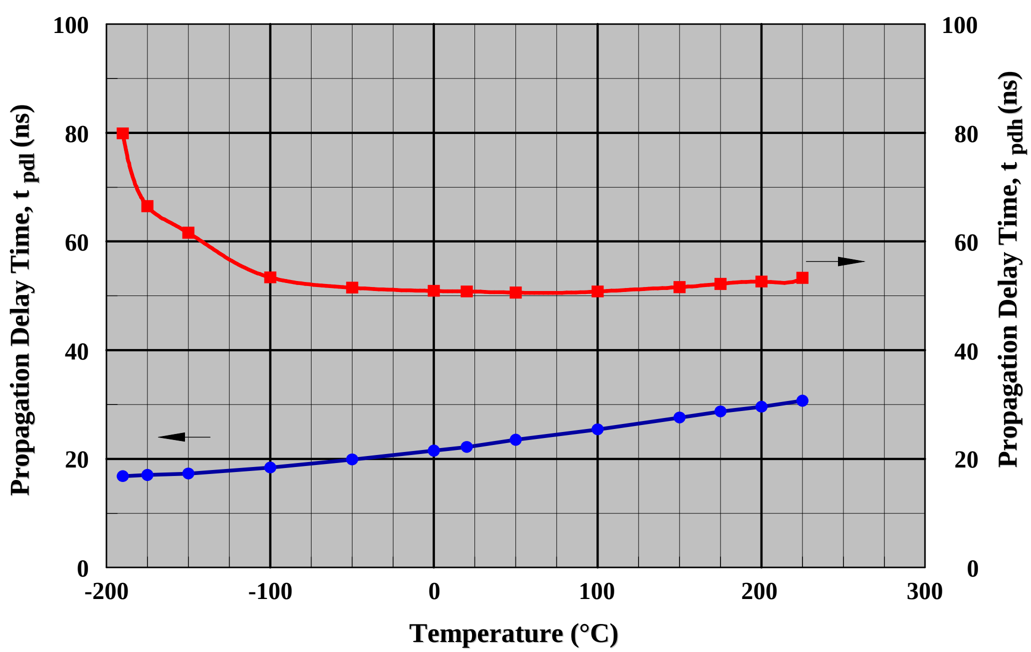


Figure 5. Transition delay times, t_{pdl} and t_{pdh}, as a function of temperature.

The duty cycle of the half-bridge driver exhibited similar behavior with temperature to that of the transition time, t_{pdh}. As shown in Figure 6, the duty cycle began to increase slightly only at test temperatures of -100 °C and lower. Figure 7 shows that the input current of the driver chip showed some modest dependency on temperature as it increased when temperature increased, and the reverse was true. The variation in the supply current amounted to about 0.9 mA over the temperature span of -190 °C to +225 °C.

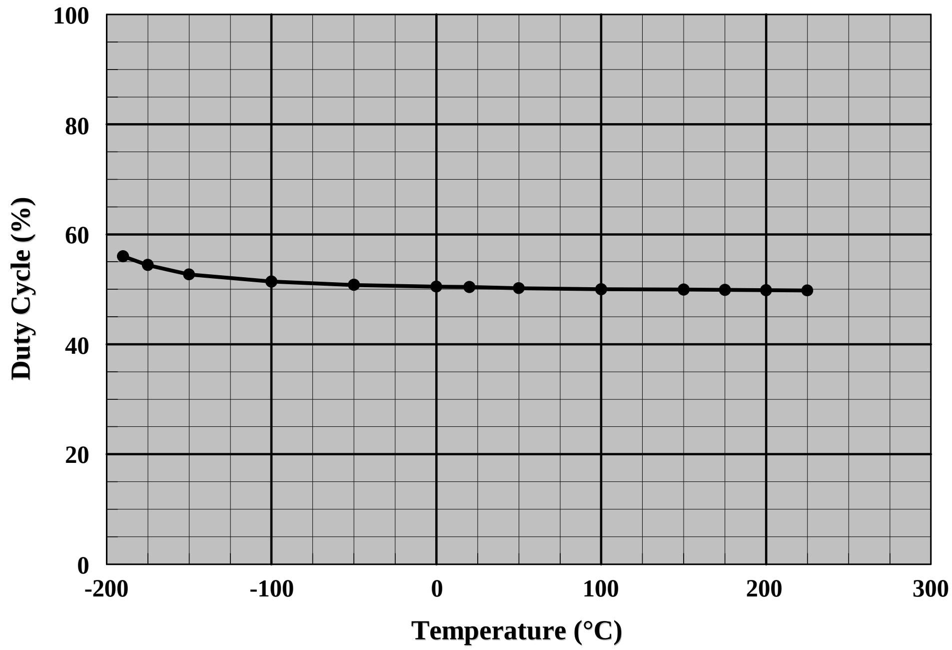


Figure 6. Duty cycle of the CHT-HYPERION as a function of temperature.

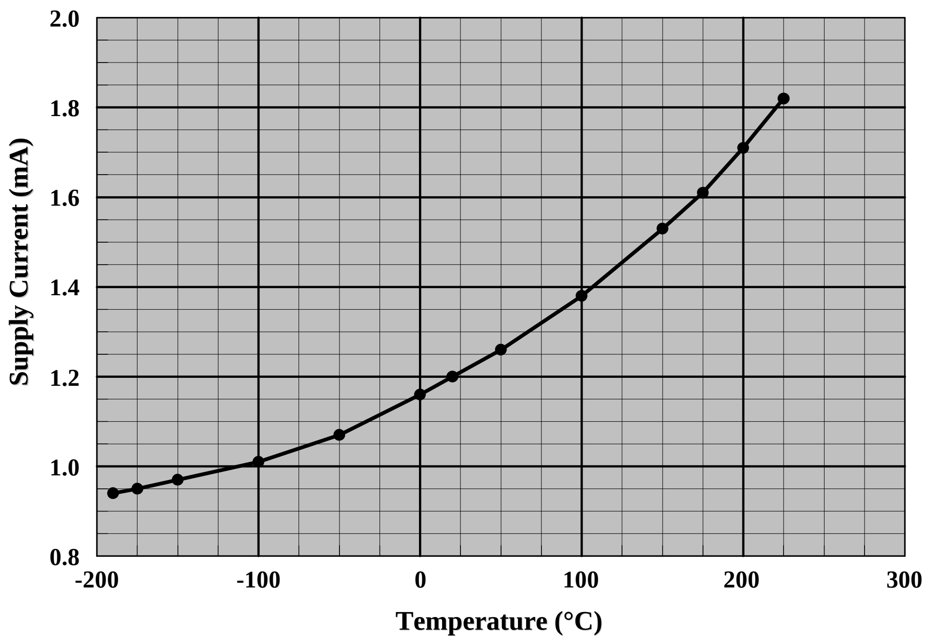


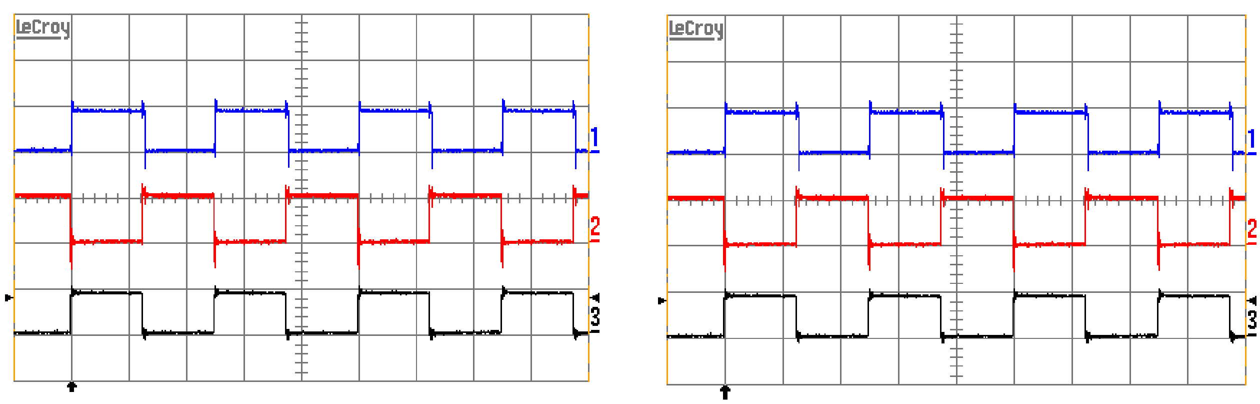
Figure 7. Supply current of the CHT-HYPERION as a function of temperature.

Restart at Extreme Temperatures

Restart capability of the CISSOID CHT-HYPERION half-bridge driver 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 °C and +225 °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.

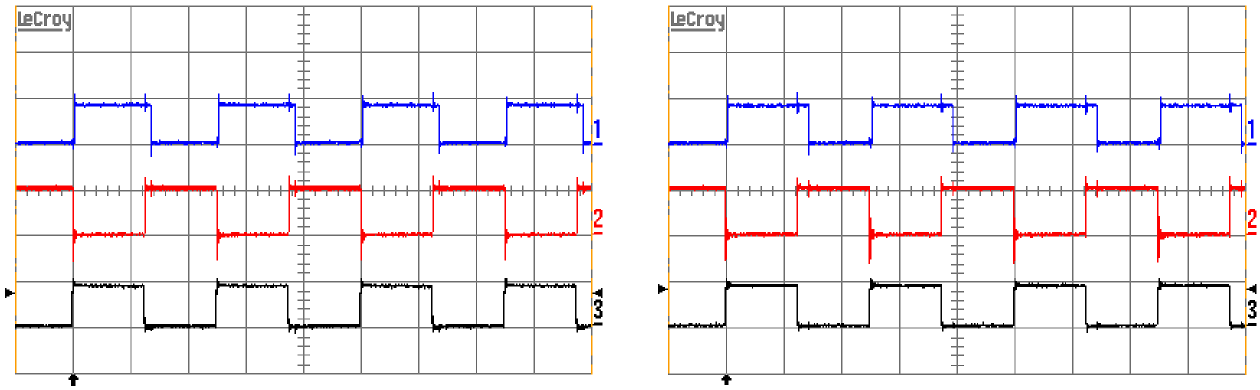
Effects of Thermal Cycling

The effects of thermal cycling over a wide temperature range were investigated by subjecting the CISSOID CHT-HYPERION half-bridge driver IC chip to a total of 12 cycles between -190 °C and +225 °C at a temperature rate of 10 °C/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 and that of the external PWM signal at the selected test temperatures of +20, -190, and +225 °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 output signals 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 circuit's signal transition delay times, duty cycle, and the current, as depicted 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 half-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.



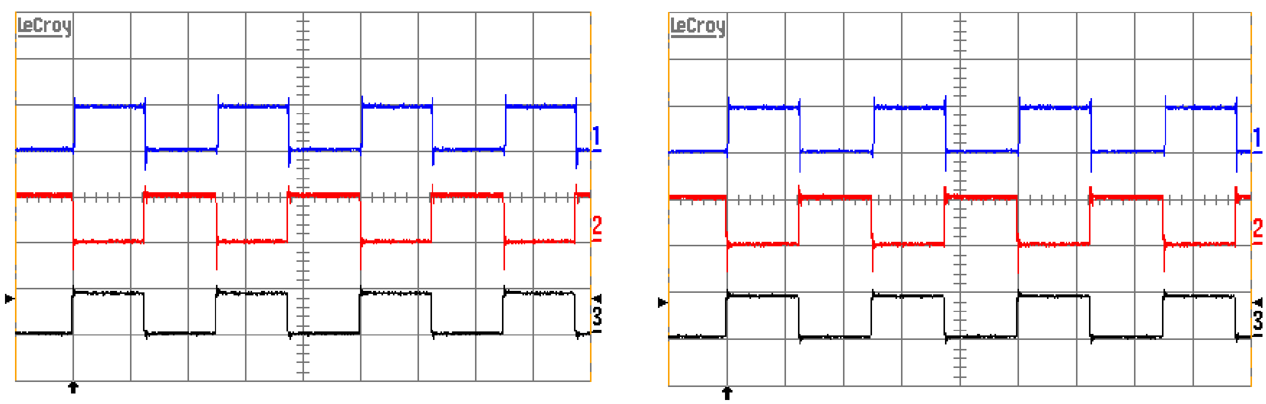
Pre-cycling   Post-cycling

Figure 8. Pre- & post-cycling signals of HSDRV (#1), LSDRV (#2), & PWM (#3) at +20°C.



Pre-cycling   Post-cycling

Figure 9. Pre- & post-cycling signals of HSDRV (#1), LSDRV (#2), & PWM (#3) at -190°C.



Pre-cycling   Post-cycling

Figure 10. Pre- & post-cycling signals of HSDRV (#1), LSDRV (#2), & PWM (#3) at +225°C.

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

	Transition Time t_{pdl} (ns)		**Transition Time t_{pdh} (ns)**		**Duty Cycle (%)**		**Input Current (mA)**	
Temp. (°C)	Pre	Post	Pre	Post	Pre	Post	Pre	Post
+20	22.2	22.3	50.8	50.2	50.4	50.4	1.20	1.20
-190	16.8	16.7	79.9	78.0	56.0	55.9	0.94	0.94
+225	30.7	30.4	53.3	52.9	49.8	49.8	1.82	1.82

Conclusions

A new SOI (silicon-on-insulator) half-bridge MOSFET driver integrated circuit chip, a CISSOID type CHT-HYPERION, 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 major change 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 half-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-HYPERION High Temperature Half-Bridge MOSFET Driver" Data Sheet, Doc. DS-090509, V1.02, October 5, 2009. http://www.CISSOID.com

Acknowledgements

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