

## NASA Electronic Parts and Packaging Program

## Performance of a 100V Half-Bridge MOSFET Driver, Type MIC4103, Over a Wide Temperature Range

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**Scope**

The operation of a high frequency, high voltage MOSFET (metal-oxide semiconductor field-effect transistors) driver was investigated over a wide temperature regime that extended beyond its specified range. The Micrel MIC4103 is a 100V, non-inverting, dual driver that is designed to independently drive both high-side and low-side N-channel MOSFETs. It features fast propagation delay times and can drive 1000 pF load with 10ns rise times and 6 ns fall times [1]. The device consumes very little power, has supply under-voltage protection, and is rated for a -40 °C to +125 °C junction temperature range. The floating high-side driver of the chip can sustain boost voltages up to 100 V. Table I shows some of the device manufacturer's specification.

Table I. Specifications of Micrel half-bridge driver chip [1].

| Parameter                                | Symbol     | MIC4103YM          |
|--|------------|--------------------|
| Digital Supply Voltage (V)               | $V_{DD}$   | 9 to 16            |
| Input Current (mA)                       | $I_{VDD}$  | 3                  |
| Input Supply Voltage (V)                 | $V_{IN}$   | -1 to 100          |
| Output Current (A)                       | $I_O$      | 2 $\tau$ 3         |
| Operating Temperature (°C)               | T(oper)    | -40 to +125        |
| Low Side Turn-On Propagation Delay (ns)  | $t_{LPLH}$ | 24                 |
| High Side Turn-On Propagation Delay (ns) | $t_{HPLH}$ | 24                 |
| Output Rise Time (ns)                    | $t_r$      | 10                 |
| Output Fall Time (ns)                    | $t_f$      | 6                  |
| Package                                  |            | Plastic 8-pin SOIC |
| Lot Number                               |            | 0828               |

The driver was configured in a circuit to drive a capacitive load using IRFP360 MOSFETs as the low and high side switches, as shown in Figure 1. The driver chip was characterized in terms of its high-side gate drive output (HO), low-side gate drive output (LO), outputs rise time, fall time, and turn-on delay time at specific test temperatures. The propagation delay times included  $t_{LPLH}$  (LI Rising to LO Rising) and  $t_{HPLH}$  (HI Rising to HO Rising). The rise and fall times of the driver output signals as well as the supply current were also recorded. The operational characteristics of the drive circuit were obtained over the test temperature range between -193 °C and +150 °C using a liquid nitrogen-cooled environmental chamber. During this evaluation, only the driver chip along with the bootstrap capacitor were subjected to temperature variation as they were

physically placed inside the chamber while the rest of the circuit was kept at room temperature outside the chamber. Re-restart capability of the circuit at extreme temperatures, i.e. power switched on while the driver chip was soaking at extreme (hot or cold) temperature, was also investigated. In addition, the effects of limited thermal cycling on the operation of high speed driver were determined by exposing it to a total of 12 cycles between  $-193\text{ }^{\circ}\text{C}$  and  $+150\text{ }^{\circ}\text{C}$  at a temperature rate of  $10\text{ }^{\circ}\text{C}/\text{minute}$ . Following the thermal cycling, circuit measurements were then performed at the test temperatures of  $+24$ ,  $-193$ , and  $+150\text{ }^{\circ}\text{C}$  using a soak time of at least 20 minutes at these test temperatures. Figure 2 shows the half-bridge driver chip mounted on a circuit board along with the ceramic bootstrap and decoupling capacitors.

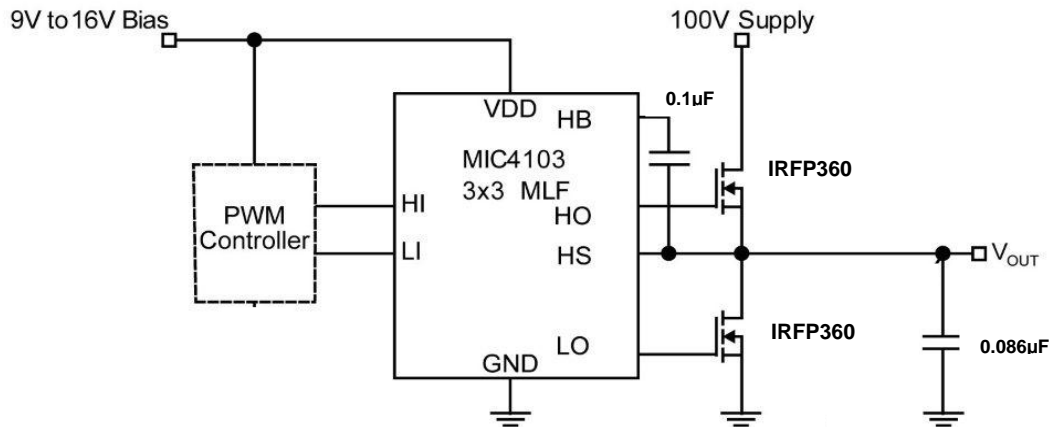


Figure 1. Schematic of test circuit of the MIC4103 half-bridge driver [1].

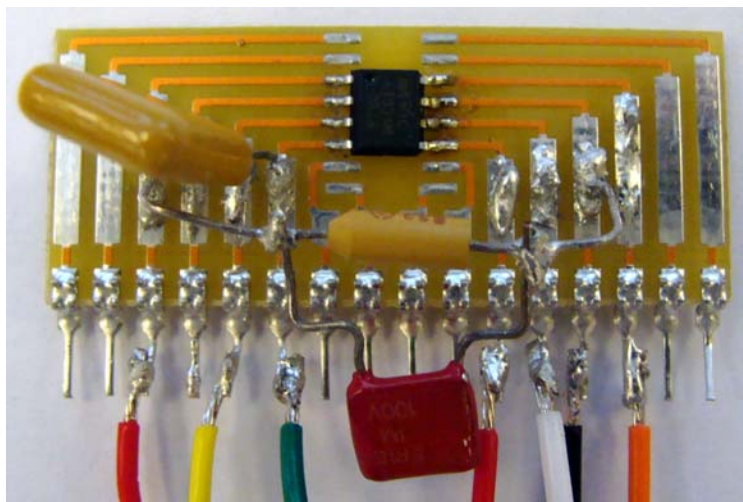


Figure 2. MIC4103 half-bridge driver and passive parts mounted on test board.

## Test Results

### Temperature Effects

Waveforms of the MIC4103 low-side driver (LO) and the high-side driver (HO) output signals along with the input signals for the low-side (LI) and high-side (HI) drives recorded at room temperature are shown in Figure 3. The operation of the circuit was examined, as mentioned earlier, over a wide temperature range and signal waveforms were also obtained at the test points of +50, +75, 100, +125, +130, +140, +145, +150, 0, -25, -50, -75, -100, -125, -150, -175, -190, and -193 °C. The circuit maintained proper operation and no major change was observed in the shape or magnitude of these waveforms as test temperature was changed throughout the range of -193 °C to +150 °C. For illustrative purposes, therefore, only waveforms obtained at the extreme temperatures of -193 °C and +150 °C are also presented here as shown in Figures 4 and 5, respectively.

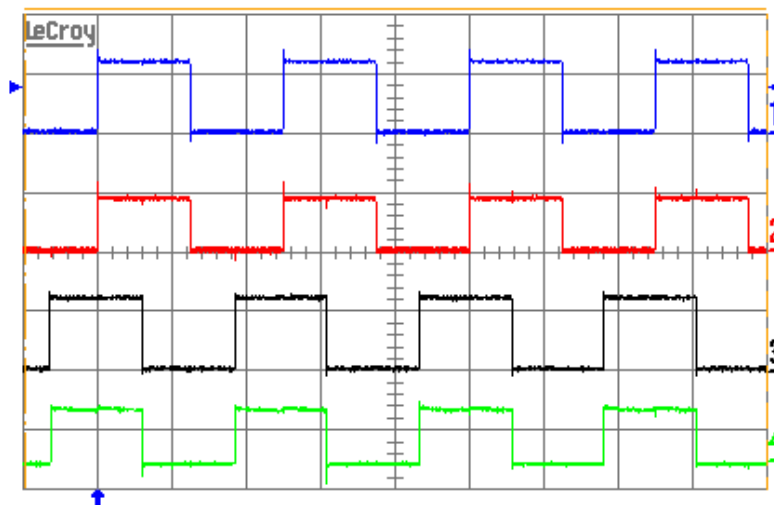


Figure 3. LI (trace 1), LO (trace 2), HI (trace 3), and HO (trace 4) signals at +24°C.  
(Scale: Vertical 5V/div for LI & HI, 10V/div for LO & HO; Horizontal 20µs/div)

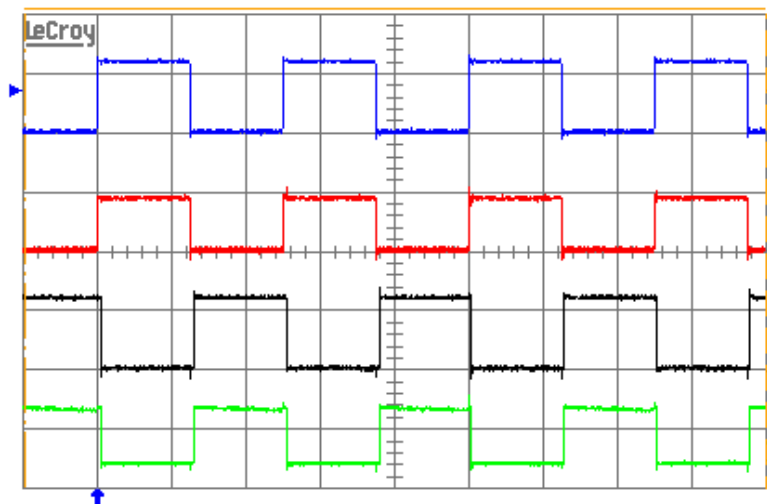


Figure 4. LI (trace 1), LO (trace 2), HI (trace 3), and HO (trace 4) signals at -193°C.  
(Scale: Vertical 5V/div for LI & HI, 10V/div for LO & HO; Horizontal 20µs/div)

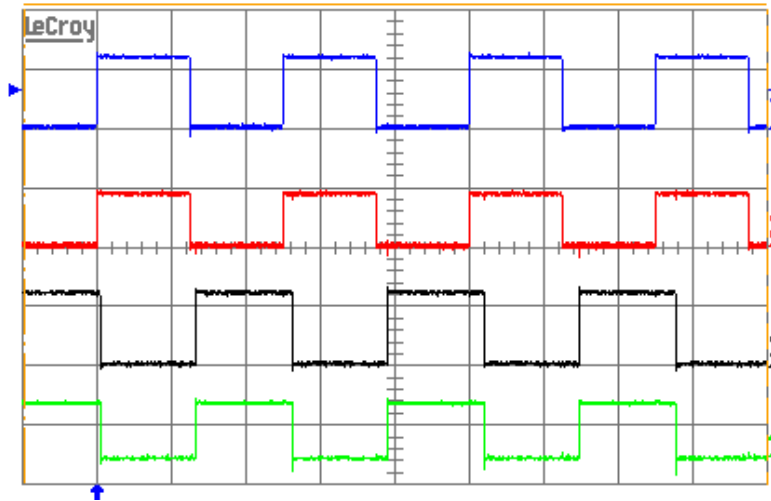


Figure 5. LI (trace 1), LO (trace 2), HI (trace 3), and HO (trace 4) signals at +150°C.  
 (Scale: Vertical 5V/div for LI & HI, 10V/div for LO & HO; Horizontal 20μs/div)

Figure 6 shows the turn-on propagation delay time  $t_{LPLH}$  for the low-side drive (LI rising to LO rising) and the turn-on propagation delay time  $t_{HPLH}$  for the high-side drive (HI rising to HO rising) of the half-bridge driver as a function of temperature. It can be seen that both drives, at any given test temperature, displayed comparable values in their turn-on propagation delay time. Similar trend was also observed in these attributes with change in temperature as the propagation delay time, for either drive, exhibited gradual but slight increase as the test conditions varied from cryogenic to high temperature, as depicted in Figure 6. This increase amounted to about doubling in the turn-on propagation delay time values as temperature was raised from -193 °C to +150 °C.

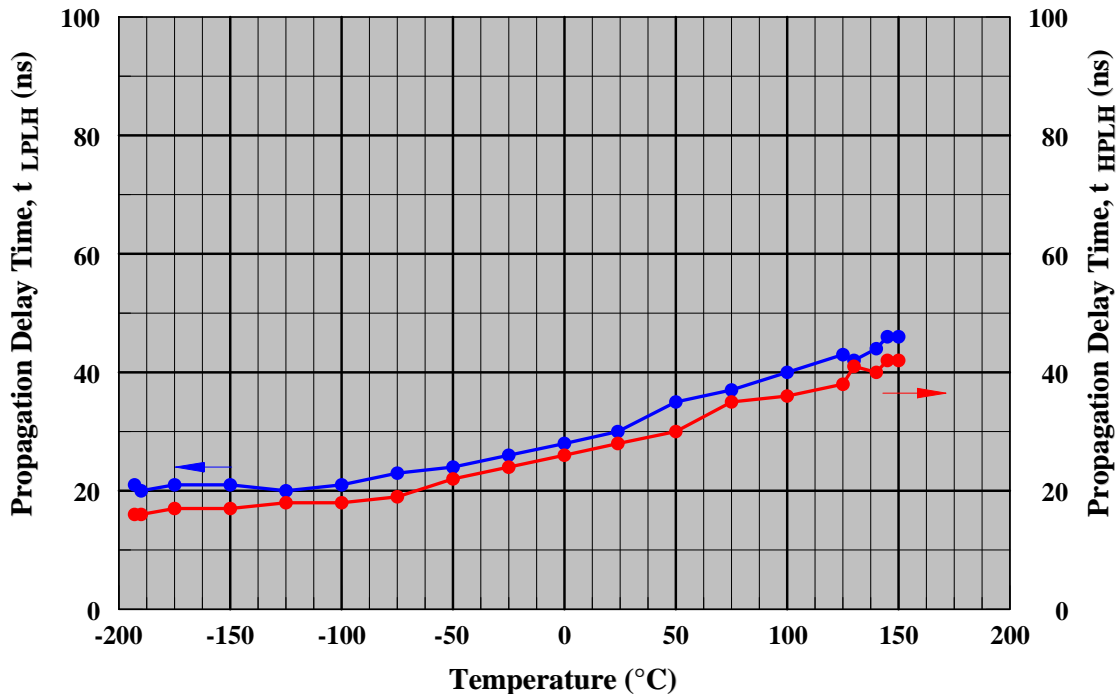


Figure 6. Turn-on propagation delay times,  $t_{LPLH}$  and  $t_{HPLH}$ , as a function of temperature.

The rise and fall time times of the output signal of the low-side driver are shown in Figure 7 as a function of temperature. Little effect of temperature was found on these characteristics of the driver as their values held a steady value of about 18 ns throughout the test temperature range. Similar behavior was observed for these properties of the other drive, i.e. high-side, as shown in Figure 8.

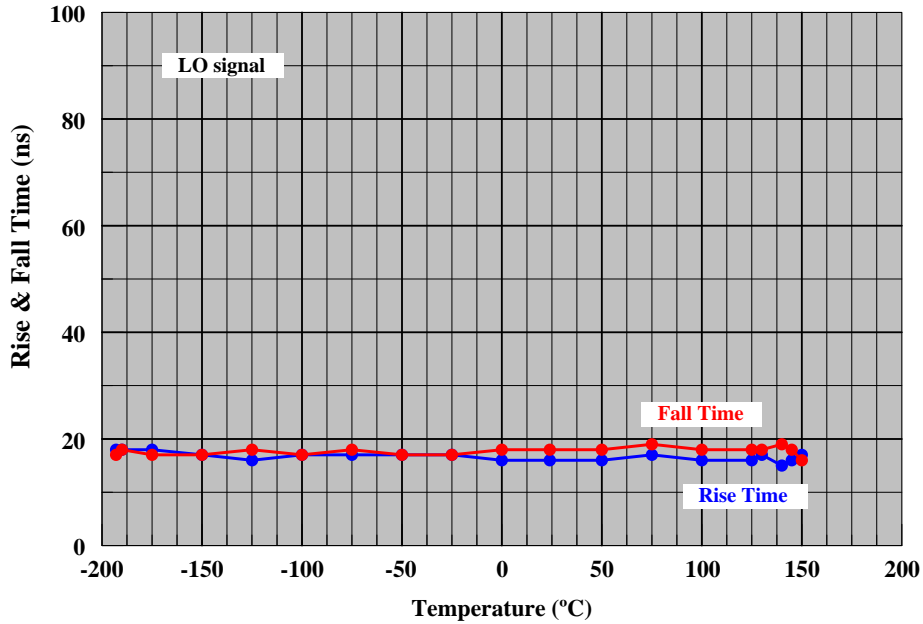


Figure 7. Rise and fall times of low-side driver output signal (LO) versus temperature.

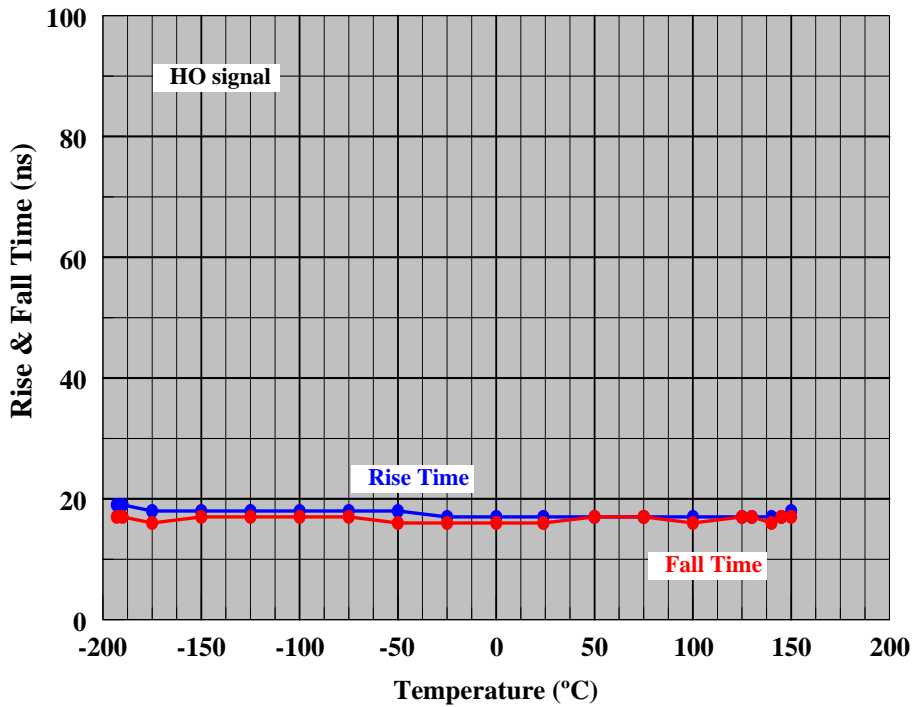


Figure 8. Rise and fall times of high-side driver output signal (HO) versus temperature.

The input current of the driver chip showed some modest dependency on temperature as it decreased when temperature increased above room temperature, and the input current increased as test temperature was lowered toward cryogenic temperature, as shown in Figure 9. This variation in the supply current, though, was not severe as the value of this property only changed from 0.87 mA at -193 °C to about 0.42 mA at +150 °C.

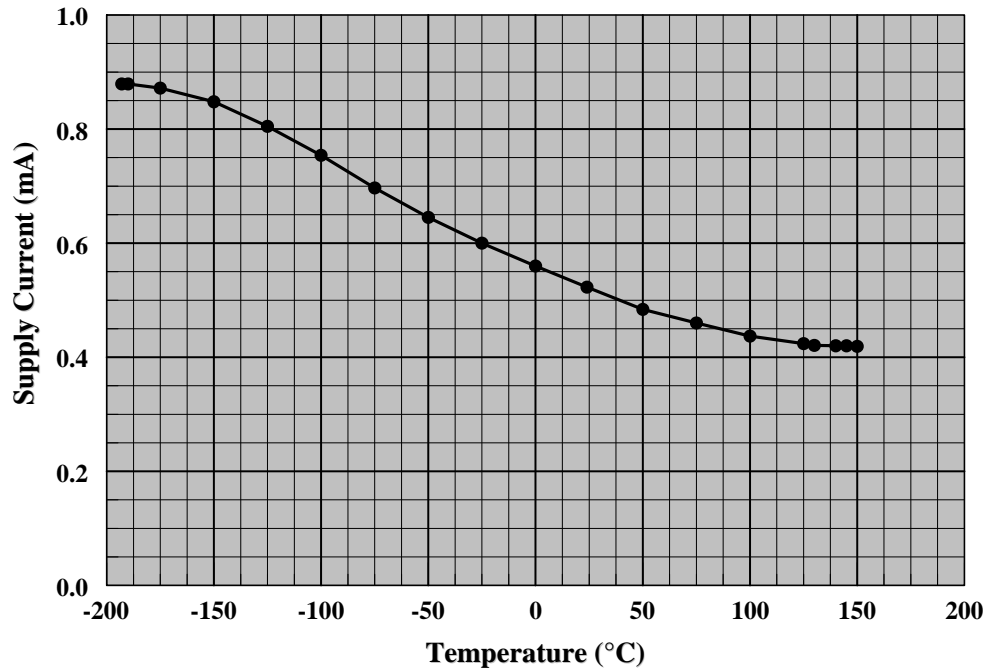


Figure 9. Supply current of the MIC4103 driver as a function of temperature.

#### *Restart at Extreme Temperatures*

Restart capability of the MIC4103 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 -193 °C and +150 °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 MIC4103 MOSFET half-bridge driver IC chip were investigated by subjecting it to a total of 12 cycles between -193 °C and +150 °C at a temperature rate of 10 °C/minute. A dwell time of 20 minutes was applied at the extreme temperatures. Following cycling, measurements of the investigated parameters were taken again as a function of temperature. A comparison of the input and output signals of both the low-side and high-side drivers at the selected test temperatures of +24, -193, and +150 °C for pre - and post-cycling conditions are shown in Figure 10. It can be clearly seen that the post-cycling signal waveforms 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 propagation delay times, switching characteristics, 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 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.

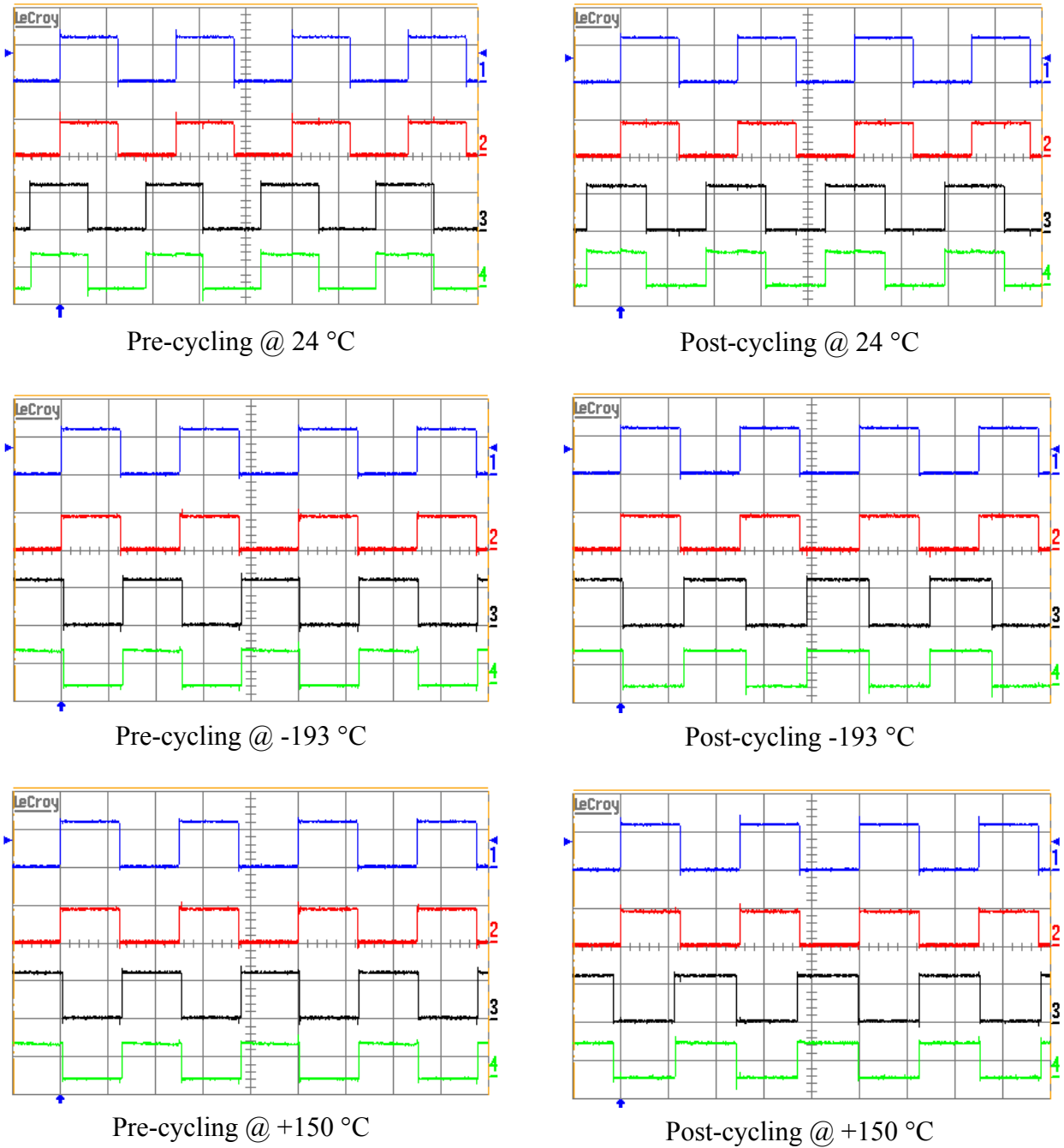


Figure 10. Pre- & post-cycling waveforms of LI (trace 1), LO (trace 2), HI (trace 3), and HO (trace 4) signals of MIC4103 half-bridge driver at selected temperatures.

Table II. Pre- & post-cycling propagation delays, switching times, & input current.

|           | Delay Time<br>$t_{LPLH}$ (ns) |      | Delay Time<br>$t_{HPLH}$ (ns) |      | LO Signal  |            | HO Signal  |            | Input Current<br>(mA) |       |
|-----------|-------------------------------|------|-------------------------------|------|------------|------------|------------|------------|-----------------------|-------|
|           | Prior                         | Post | Prior                         | Post | $t_r$ (ns) | $t_f$ (ns) | $t_r$ (ns) | $t_f$ (ns) | Prior                 | Post  |
| Temp (°C) |                               |      |                               |      |            |            |            |            |                       |       |
| +24       | 30                            | 31   | 28                            | 29   | 16         | 16         | 17         | 16         | 0.523                 | 0.518 |
| -193      | 21                            | 18   | 16                            | 16   | 18         | 16         | 19         | 17         | 0.879                 | 0.854 |
| +150      | 46                            | 44   | 42                            | 42   | 17         | 16         | 18         | 16         | 0.419                 | 0.418 |

## Conclusions

A new 100V half-bridge MOSFET driver integrated circuit chip, a Micrel type MIC4103, was evaluated for operation at temperatures beyond its recommended specified limits of -40 °C to +125 °C. The effects of thermal cycling under the extended test temperature, which ranged from -193 °C to +150 °C, on the operation of this chip as well as restart capability at the extreme cryogenic and hot temperatures were also investigated. The driver circuit was able to maintain good operation throughout the entire test regime between -193 °C and +150 °C without undergoing any major changes in its outputs signals and characteristics. The limited thermal cycling performed on the device also had no effect on its performance, and the driver chip was able to successfully restart at each of the extreme temperatures of -193 °C and +150 °C. The plastic packaging of this device was also not affected by either the short extreme temperature exposure or the limited thermal cycling. These preliminary results indicate that this commercial-off-the-shelf (COTS) half-bridge MOSFET driver integrated circuit has the potential for use 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]. Micrel Incorporation “MIC4103/4104 100V Half Bridge MOSFET Drivers 3/2A Sinking/Sourcing Current” Data Sheet, M9999-110910-B, November 2010. <http://www.micrel.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”.