November 2010

NASA Electronic Parts and Packaging Program

# Evaluation of Fairchild's Gate Drive Optocoupler, Type FOD3150, under Wide Temperature Operation

Richard Patterson, NASA Glenn Research Center
Ahmad Hammoud, ASRC Corp., NASA GRC
Scott Panko, ASRC Corp., NASA GRC

## Background

An optocoupler is a semiconductor device that is used to transfer a signal between different parts of a circuit that need to be electrically isolated from one another - for example, where a high voltage is to be switched with a low voltage control signal. Optocouplers often can be used in place of relays. These optocouplers utilize an infrared LED (light emitting diode) and a photodetector such as a silicon controlled rectifier or photosensitive silicon diode for the transfer of the electronic signal between components of a circuit by means of a short optical transmission channel. For maximum coupling, the wave-length responses of the LED and the detector should be very similar. In switch-mode power supply applications, optocouplers offer advantages over transformers by virtue of simpler circuit design, reduced weight, and DC coupling capability.

The effects of extreme temperature exposure and thermal cycling on the performance of a commercial-off-the-shelf (COTS) optocoupler, Fairchild FOD3150, were evaluated in this work. This 1.0 A output current, high noise immunity gate drive optocoupler utilizes an aluminum gallium arsenide (AlGaAs) LED, is capable of driving most 800V/20A IGBT/MOSFETs, and is suited for fast switching in motor control inverter applications and high performance power systems [1]. Some of the specifications of the isolator chip are listed in Table I. The device was evaluated in terms of output response, output rise ($t_r$) and fall times ($t_f$), and propagation delays (using a 50% level between input and output during low to high ($t_{PLH}$) and high to low ($t_{PHL}$) transitions). The output supply current was also obtained. These parameters were recorded at various test temperatures between -190°C and +110°C.

Table I. Manufacturer specifications of Fairchild FOD3150 optocoupler [1].

| Parameter | Symbol | FOD3150 |
|---|---|---|
| Supply Voltage (V) | $V_{DD}$ | 15 to 30 |
| Input Current (mA) | $I_{F(ON)}$ | 7 to 16 |
| Output Current Drive (A) | $I_o$ | 1.0 |
| Operating Temperature (°C) | $T_{oper}$ | -40 to +100 |
| Output Rise Time (ns) | $t_r$ | 60 |
| Output Fall Time (ns) | $t_f$ | 60 |
| Propagation Delay Time (ns) | $t_{PLH}$ | 100 to 500 |
| Propagation Delay Time (ns) | $t_{PHL}$ | 100 to 500 |
| Package | | Plastic 8-pin DIP |
| Lot Number | | 0951B |

In addition, the effects of thermal cycling on the performance of the chip were determined by exposing it to a total of 12 cycles over the test temperature range. Following the cycling activity, measurements were performed again at the test temperatures of -190°C, +23°C, and +110°C. Finally, restart operation capability of the isolator chip under extreme temperatures was investigated by first soaking the device for a period of 20 minutes at either extreme of -190 °C or +110 °C with power off, followed then by applying power to the device and recording its characteristics.

**Results and Discussion**

*Temperature Effects*

Waveforms of the input and the output signal for the FOD3150 optocoupler (with a 50% input duty cycle) at room temperature are shown in Figure 1. These waveforms were also obtained for all other test temperatures in the range from -190 °C to +110 °C. The circuit was found to operate properly without any major changes in its characteristics as test temperature varied from -100 °C to +110 °C. At temperatures below -100 °C, however, the device maintained operation but at the expense of gradual increase in its output's duty cycle as temperature decreased. At -190 °C, for example, the duty cycle reached about 73% as compared to the steady 50 % level held between -100 °C and +110 °C, as depicted in Figures 2-3. The effect of cryogenic temperatures on the duty cycle of the optocoupler is further illustrated in Figure 4.

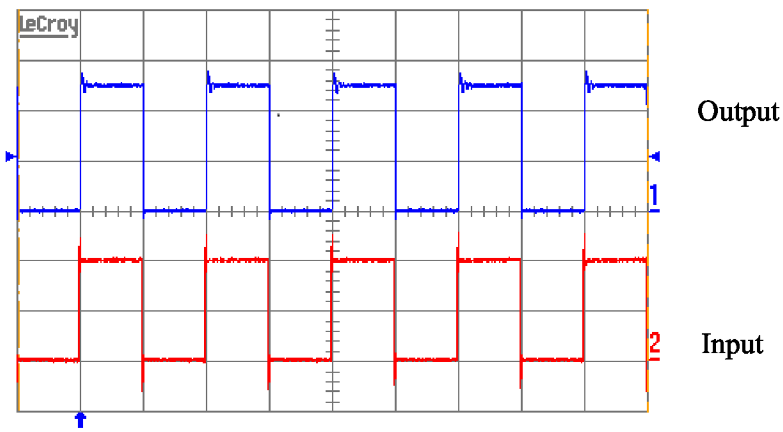



Figure 1. Input and output signal waveforms of optocoupler at +23 °C.

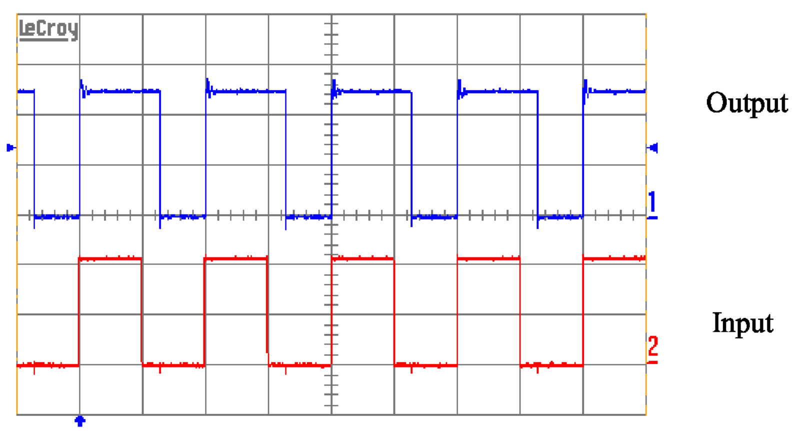



Figure 2. Input and output signal waveforms of optocoupler at -190 °C.

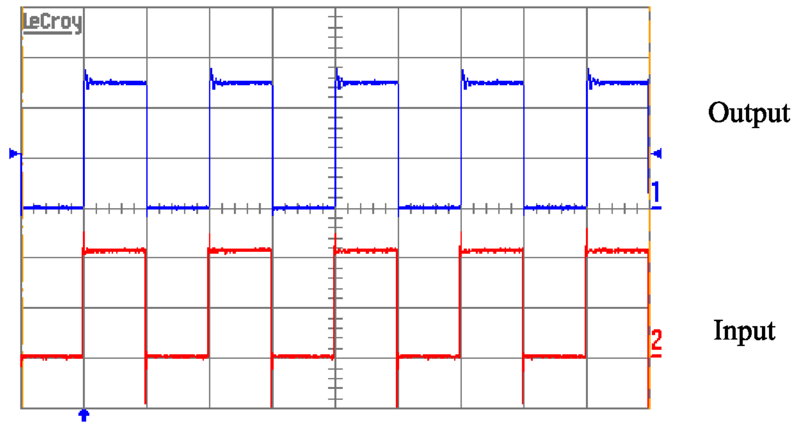



Figure 3. Input and output signal waveforms of optocoupler at +110 °C.

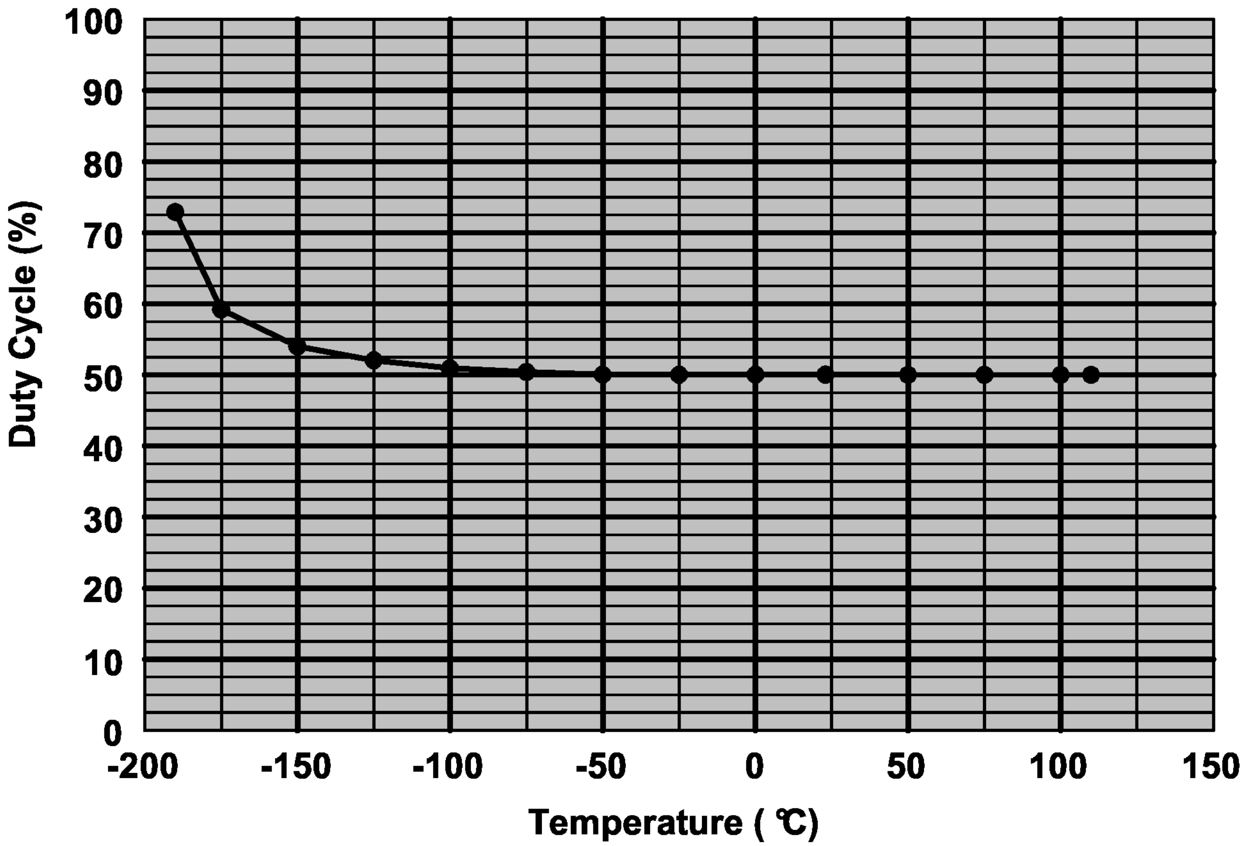



Figure 4. Duty cycle of the output signal of the FOD3150 optocoupler (with an input duty cycle of 50 %) versus temperature.

The rise and fall times of the output signal of the optocoupler were also investigated in this evaluation. Figure 5 shows the variation in these properties as a function of temperature. The trend in the rise and the fall times was very similar as both properties exhibited gradual, but very minimal, increase with increasing test temperature, as shown in Figure 5.

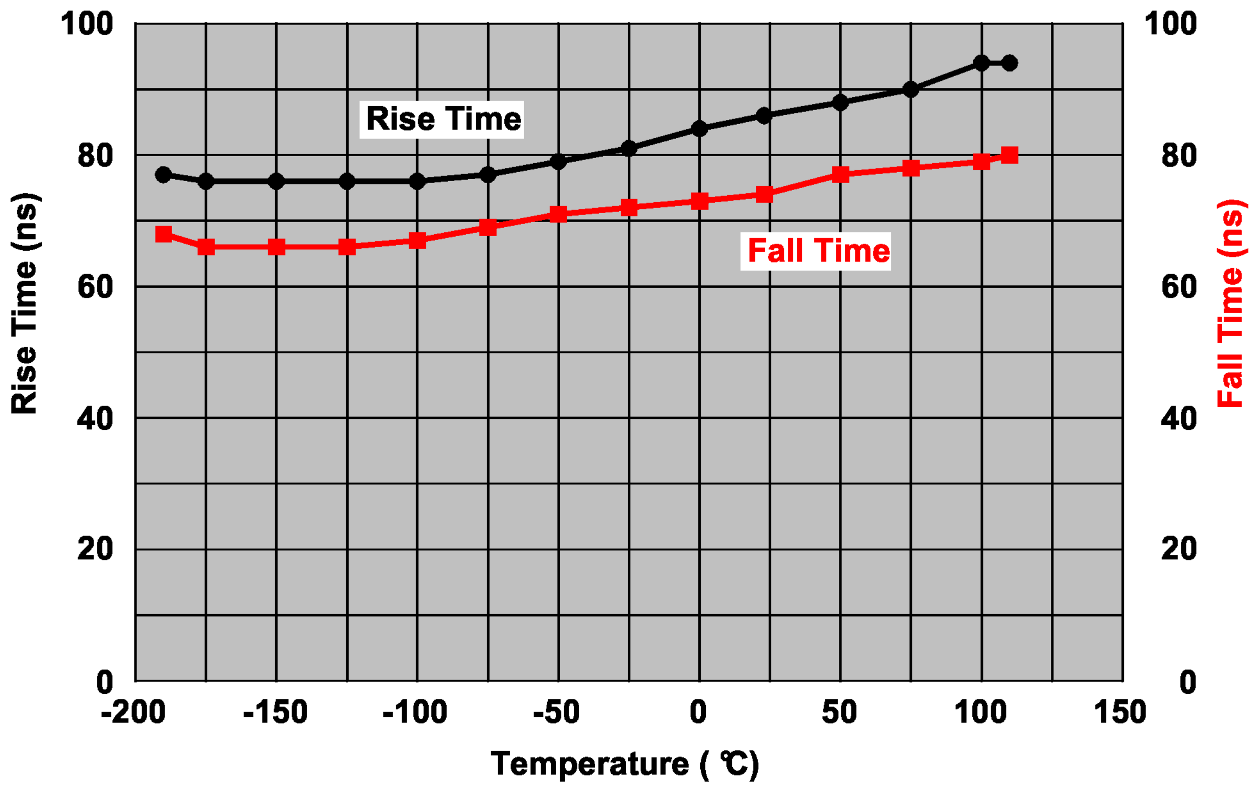


Figure 5. Rise and fall times of output signal of FOD3150 optocoupler.

The other timing parameters evaluated for the FOD3150 optocoupler were the propagation delay times at 50% level between input and output signals. These delays were measured for both the low-to-high ($t_{PLH}$) and high-to-low ($t_{PHL}$) transitions and are depicted in Figure 6. The value of $t_{PLH}$ was found to hover around 200 ns within the temperature range of -50 °C to -150 °C, but exhibited a slight, gradual increase when testing was commenced at temperatures either side outside this envelope. At the extreme test temperatures of -190 °C or +110 °C, for example, $t_{PLH}$ reached a value of about 300 ns, as shown in Figure 6. Unlike $t_{PLH}$, the high-to-low transition, $t_{PHL}$, displayed different behavior with temperature. While this property did not undergo any appreciable change as test temperature was varied from -50 °C to +110 °C, it exhibited gradual, but intense, increase as the temperature was decreased from -50 °C to -190 °C, as shown in Figure 6. Note the change in the scale in this figure to allow illustration of the severity of this change, i.e. from about 260 ns at -50 °C to over 23 µs at -190 °C. It is important to note that this change correlates with that associated with the change in the duty cycle in the cryogenic temperature region, as was mentioned earlier.

Variation in the output supply current of the FOD3150 optocoupler circuit is shown in Figure 7. The output consisted of 24 Ω in series with 10 nF. It can be seen that the supply current exhibited gradual, but very slight, decrease as test temperature increased above room temperature. At the other end, however, the supply current increased slightly as test temperature was lowered from 23 °C to -50 °C, but then reversed direction to a modest decrease as temperature was decreased further, as shown in Figure 7. The reduction in the supply current at both extreme temperatures, albeit small, is beneficial as this translates into low power consumption by the device.

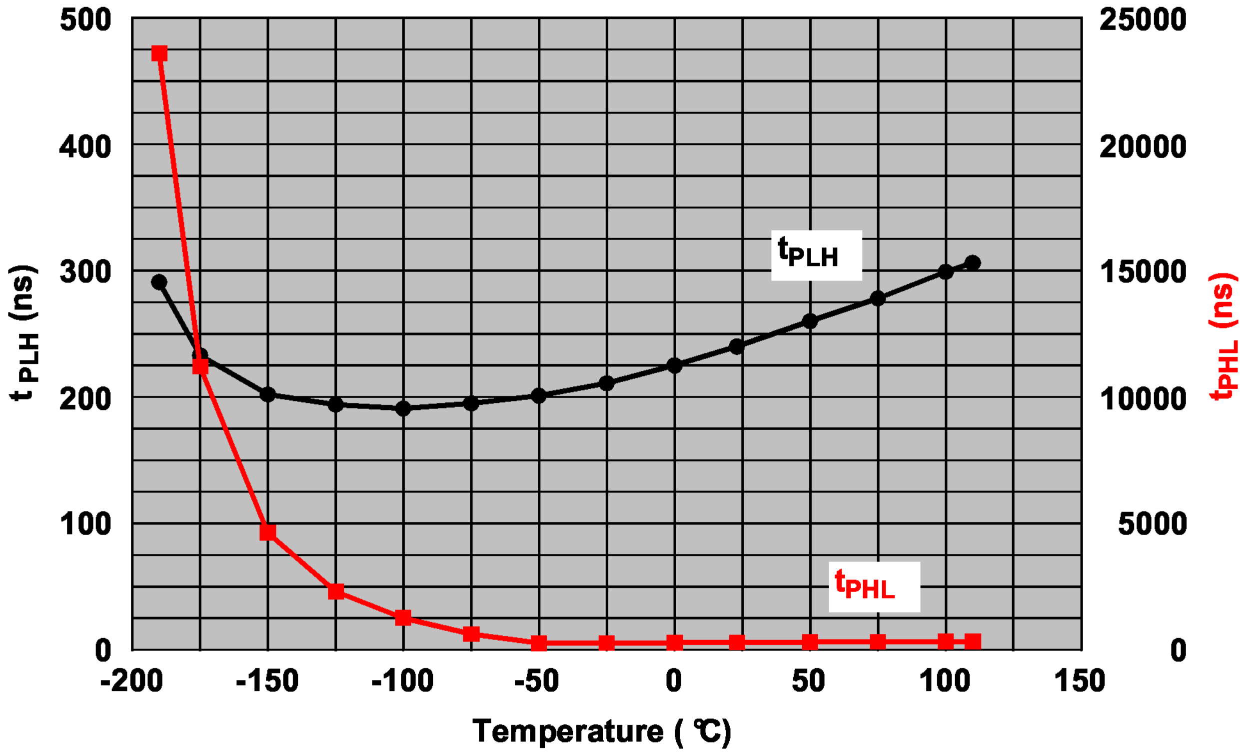



Figure 6. Propagation delay times versus temperature for the FOD3150 optocoupler.

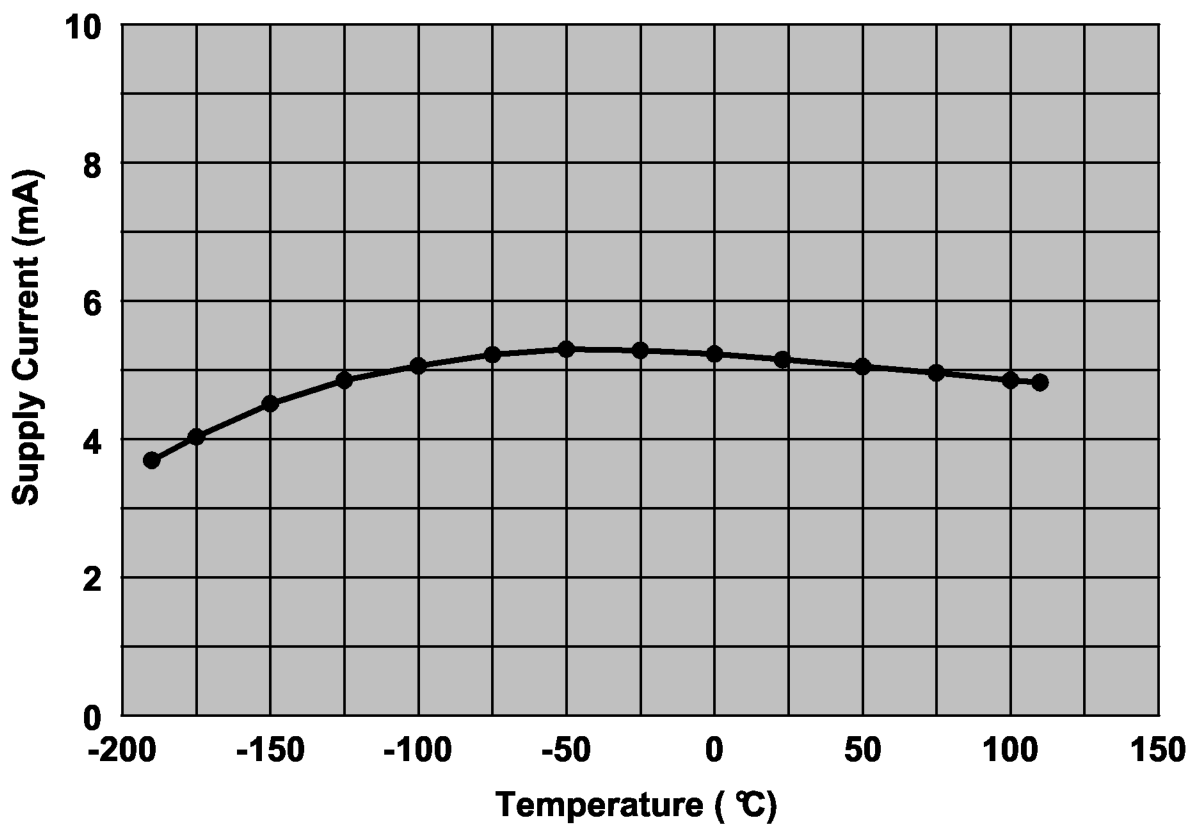



Figure 7. Supply current as a function of temperature of the FOD3150 optocoupler.

*Effects of Thermal Cycling*

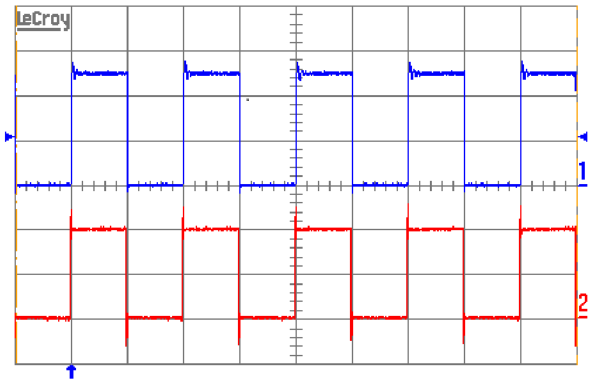
The effects of thermal cycling on the operation of the FOD3150 optocoupler were determined by exposing the chip to a total of 12 cycles between -190 °C and +110 °C at a rate of 10 °C/min. The circuit was powered while the cycling activity was taking place. In addition to the pre-cycling data, readings of the investigated properties were taken during as well as after the cycling. Table II shows the pre- and post-cycling values of the investigated properties at the selected temperatures of -190 °C, 23 °C, and 110 °C. The data presented in this table, along with output waveforms shown in Figure 8, indicate that the cycling had little effect on the circuit as few significant changes were registered between the pre- and post-cycling values of the investigated properties. The limited cycling also seemed not to affect the packaging of the chip as no physical damage was observed.

Table II. Pre- and post-cycling data at selected temperatures.

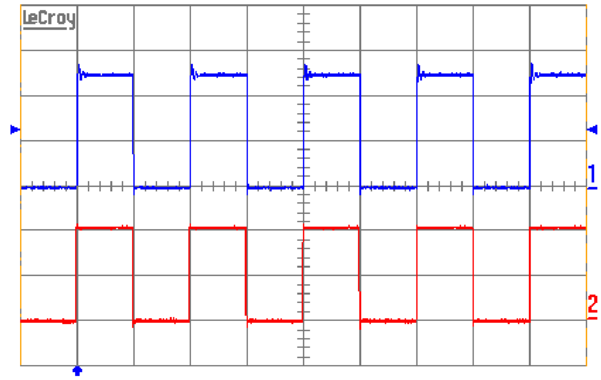
| T (°C) | $I_s$ (mA) | | $t_r$ (ns) | | $t_f$ (ns) | | $\tau_{PLH}$ (ns) | | $\tau_{PHL}$ (ns) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Prior | Post | Prior | Post | Prior | Post | Prior | Post | Prior | Post |
| -190 | 3.69 | 4.15 | 77 | 57 | 68 | 57 | 291 | 375 | 23605 | 15327 |
| +23 | 5.15 | 5.22 | 86 | 70 | 74 | 63 | 240 | 361 | 289 | 237 |
| +110 | 4.82 | 4.94 | 94 | 81 | 80 | 70 | 306 | 312 | 328 | 265 |

*Restart at Extreme Temperatures*

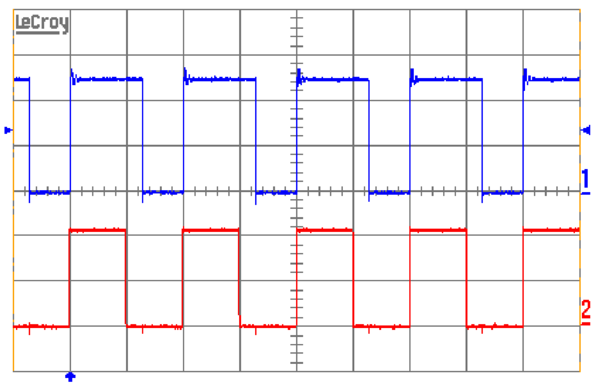
Restart capability of the optocoupler device at extreme temperatures was investigated by allowing it to soak for at least 20 minutes at each of the test temperatures of -190 °C and +110 °C without electrical bias. Power was then applied to the circuit, and measurements were taken on its output characteristics. The circuit was able to successfully restart at both extremes, i.e. -190 °C and +110 °C, and the results obtained were the same as those attained earlier for both temperatures.



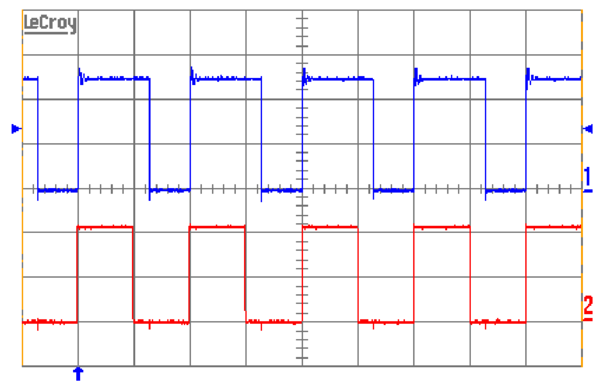
Pre-cycling at 23 °C



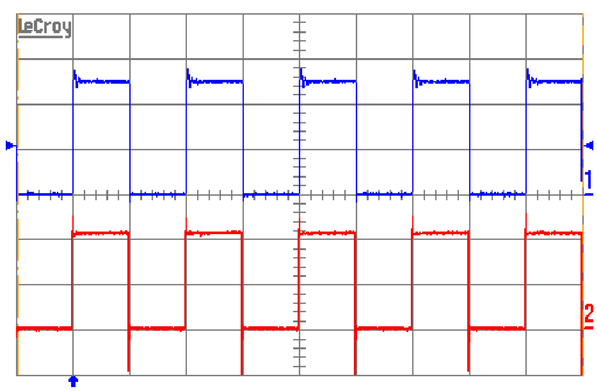
Post-cycling at 23 °C



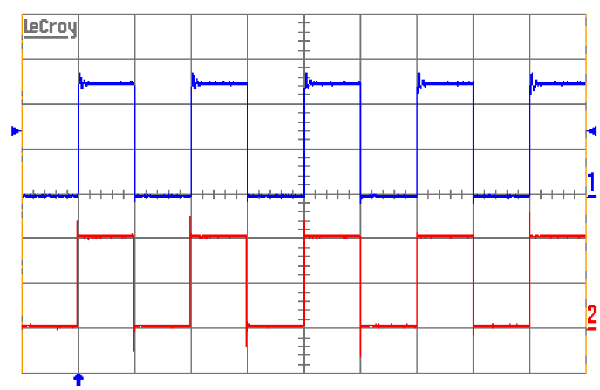
Pre-cycling at -190 °C



Post-cycling at -190 °C



Pre-cycling at +110 °C



Post-cycling at +110 °C

Figure 8. Pre- & post-cycling waveforms of input (red) & output (blue) signals @ 23, -190, & +110 °C.

## Conclusion

The operation of a commercial-off-the-shelf (COTS) optocoupler, Fairchild FOD3150, was evaluated under extreme temperature exposure and thermal cycling. The 1.0 A output current gate drive optocoupler utilizes an aluminum gallium arsenide (AlGaAs) LED and is specified for operation between -40 °C and +100 °C. The device was evaluated in this work to determine its capability of operation at temperatures outside its specified envelope. Performance of the device was obtained in terms of output response and timing characteristics over the extended temperature range of -190 °C to +110 °C. The effects of thermal cycling and restart capability at extreme temperatures were also investigated. The device was found to operate properly without any major changes in its characteristics in the temperature range from about -100 °C to +110 °C. At temperatures below -100 °C, however, the device maintained operation but exhibited a marked increase in its output's duty cycle and a significant increase in its high-to-low transition time, $t_{PHL}$ as temperature decreased. At -190 °C, for example, the duty cycle reached about 73% as compared to the steady 50 % level held between -100 °C and +110 °C. Such variation might not be acceptable, for example, if the device were to serve as a gate control in motor drive applications. It should be pointed out that these anomalies occur at temperatures well beyond its specified range. The limited thermal cycling, which comprised of 12 cycles between -190 °C and +110 °C, had no influence on either its performance or packaging, and the chip was able to restart at the extreme test temperatures. These preliminary results indicate that this semiconductor chip has the potential for use at temperatures slightly beyond the specified levels but additional testing is needed to establish its operation characteristics and reliability under long term use for application in space exploration missions.

## References

[1]. Fairchild Semiconductor Corporation, "FOD3150 High Noise Immunity, 1.0A Output Current, Gate Drive Optocoupler," Data Sheet FOD3150 Rev. 1.0.3, May 2010. http://www.fairchildsemi.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."