Experimental Evaluation of Cryogenic Performances of Electronic Components for Signal Isolation in Medium Voltage Power Converters

Shimul Dam[1], Ching-Hsiang Yang[1], Zhou Dong[3], Dehao Qin[2], Ruirui Chen[1], Fred Wang[1,4], Hua Bai[1], and Zheyu Zhang[2]
[1] The University of Tennessee, Knoxville
[2] Clemson University
[3] ABB US Research Center
[4] Oak Ridge National Laboratory

INTRODUCTION:

- Power converters at cryogenic temperature (<-153^{0}C) can offer improved efficiency and power density.
- Cryogenic performances of power semiconductors and other power circuit components have been studied in literature[1].
- This work studies the cryogenic performance of isolated auxiliary power supplies (APS), digital isolators, fiber optics, and isolation amplifiers, which are essential for providing signal isolation in a power converter.
- Commercially available components selected for an application which requires 6.5 kV voltage isolation and well performing candidates are identified.

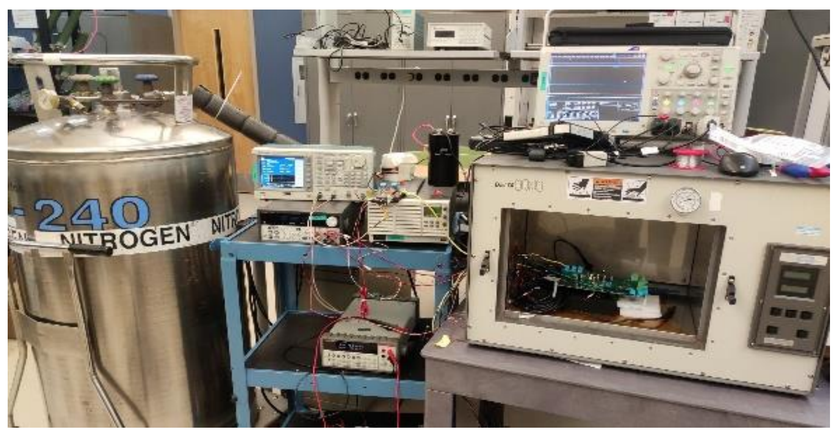

Fig. 1. Test setup with temperature chamber and liquid Nitrogen.

AUXILIARY POWER SUPPLY

- 12V-12V isolated power supplies are chosen as auxiliary power supplies for gate drivers and other signal circuits
- All APSs are tested from 60^{0}C to -180^{0}C at 10% and 80% load conditions
- Seven different APSs are tested and three of them are found to work well over entire range of temperature and load.
- All APSs work well at 80% load conditions due to higher loss, resulting in higher internal temperature.
- APSs with lower switching frequency performed worse.

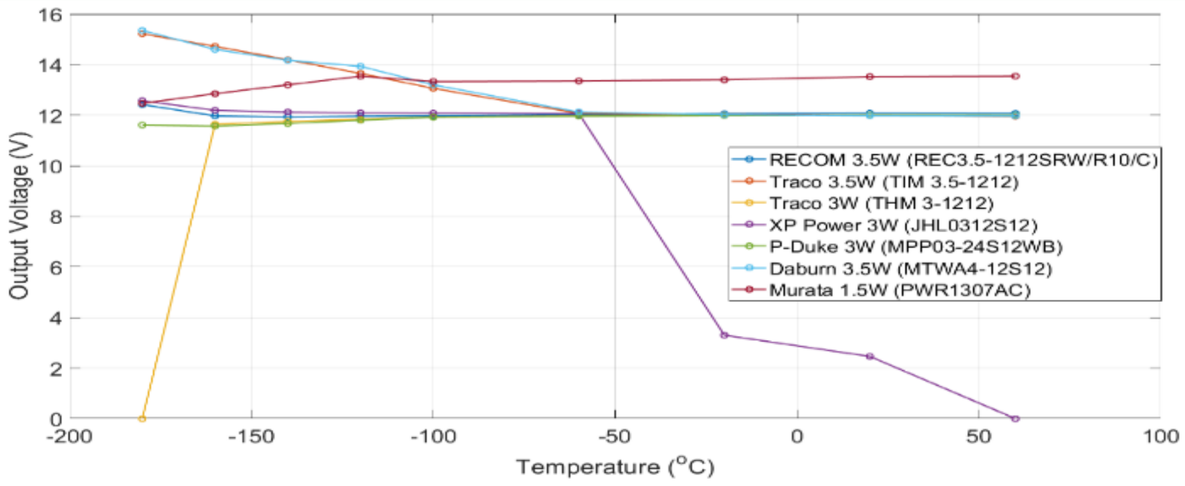

Fig. 2. Output voltages of the selected APSs over test temperature range at 10% load condition.

FIBRE OPTICS AND DIGITAL ISOLATORS

- Fiber optics links are often preferred due to its high voltage isolation and high noise immunity.
- Two popular fiber optic transmitter-receiver pairs, the AFBR and ToshLink series are tested at cryogenic temperature.
- AFBR series offers a lower signal propagation delay but fails at -110^{0}C.
- The Toshlink series has better temperature range and fails at -150^{0}C.
- The Toshlink receiver is based on CMOS, which performs better at cryogenic temperature compared to BJT-based TTL technology [2] of the AFBR receiver.

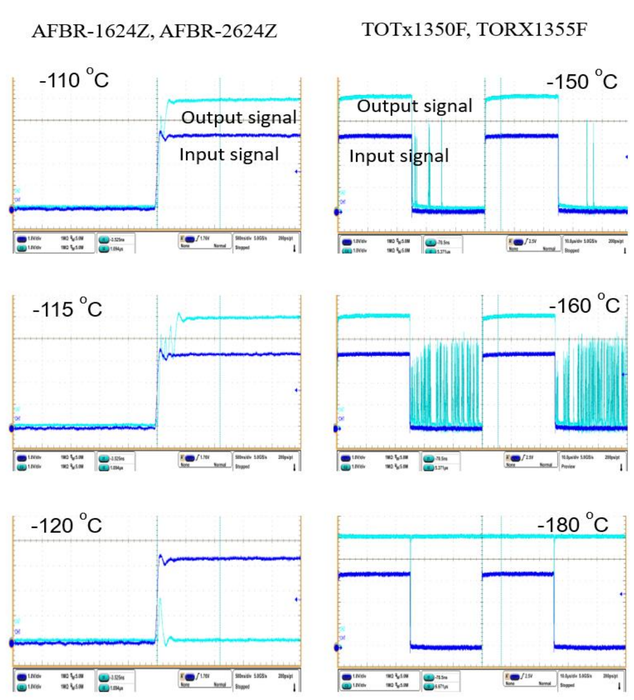

Fig. 3. Input and output signals of fiber optic receiver-transmitter pairs.

- Five different digital isolators selected based on their propagation delays and isolation voltage ratings.
- All of the selected digital isolators performed well over the entire temperature range with small variation in their propagation delays.

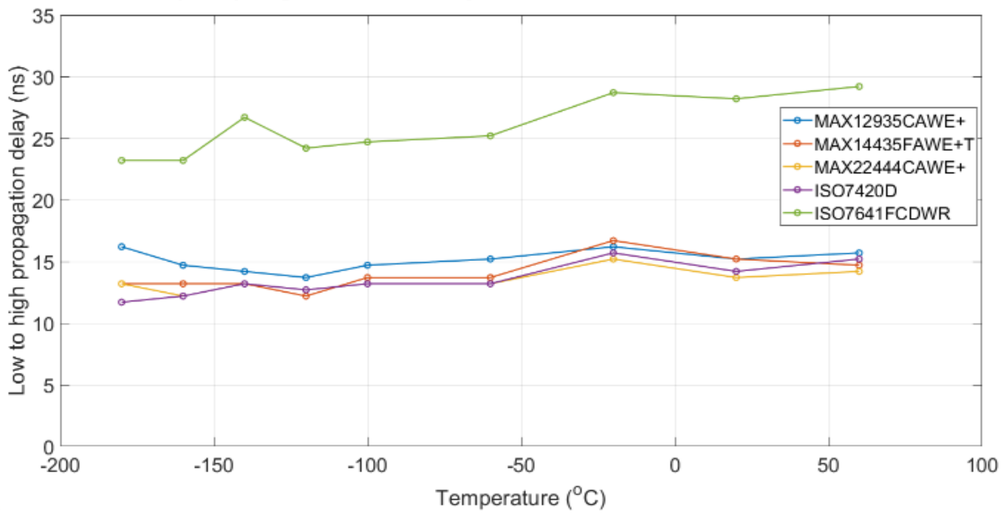

Fig. 4. Propagation delays of digital isolators during low-high transition

ISOLATION AMPLIER

- First amplifier (ADUM3190TRQZ) shows lower gain at lower temperatures. The other two amplifiers (AMC1202 and AMC1302) show very stable gains
- The ADUM3190 uses magnetic isolation and the AMC1202 and 1302 use capacitive isolation. Degradation of core characteristics at the cryogenic temperatures [3] may cause poor performance of ADUM3190.

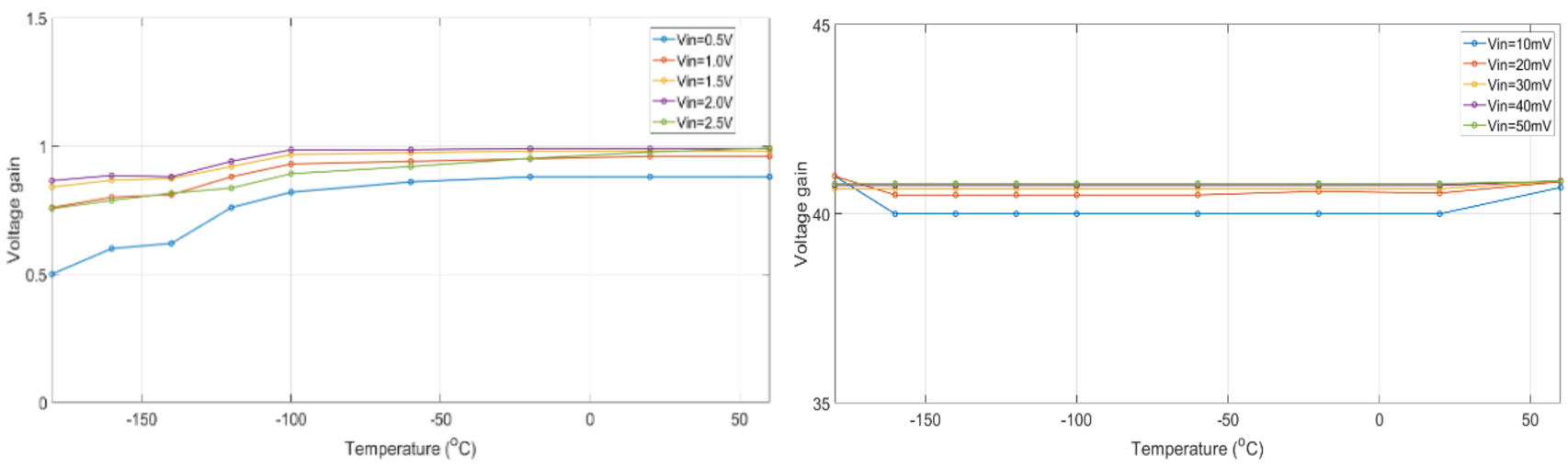

Fig. 5. (a) Voltage gain of ADUM3190TRQZ (nominal gain = 1), (b) Voltage gain of AMC1202DWVR (nominal gain = 41)

CONSLUSION

- Experimental evaluation of cryogenic performance of commercially available isolated auxiliary power supplies, digital isolators, fiber optic transmitter-receivers, and isolation amplifiers is presented.
- It is observed that APSs with higher switching frequency and isolation amplifier with capacitive isolation performs well.
- Digital isolators performs better than fiber optic links at cryogenic temperature.
- Theses findings will be helpful to select components for cryogenic applications.

REFERENCES

1. Z. Zhang, et. al., "Characterization of high-voltage highspeed switching power semiconductors for high frequency cryogenically-cooled application," in Applied Power Electronics Conference and Exposition, Tampa, FL, 2017.
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3. R. Chen, et. al., "Core Characterization and Inductor Design Investigation at Low Temperature," in 2018 IEEE Energy Conversion Congress and Exposition (ECCE), Portland, OR, USA, 2018.