Lunar Orbital Platform–Gateway Gigabit Ethernet Media Converter

Team 23

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Abstract

The variety of different communication technologies on the Lunar Orbital Platform–Gateway (LOP–G) necessitates a converter to allow proper interfacing. The goal of this capstone was to propose a prototype converter and present it to Honeywell for further development. The prototype design converts bidirectionally between copper and fiber optic Gigabit Ethernet (GbE) signals, under a variety of power levels and Electromagnetic Interference (EMI). Results indicate that the prototype correctly translates data between fiber optic and copper GbE, meets timing requirements outlined in the IEEE GbE standard, and is tolerant to EMI and overvoltage surges, while minimizing the Size, Weight, and Power (SWaP). Testing proved the prototype was functional and met the desired specifications. This project was a success, and lays the groundwork for future innovation in electrical engineering.

Motivation

LOP–G is an international collaborative space station headed by NASA. It will orbit the moon and serve as a launch point for future space missions. Onboard communications are facilitated through two forms of Gigabit Ethernet (GbE), each with their own advantages: copper twisted pair and fiber optics. Copper is extensively used and field–proven both on Earth and in historic space missions, and its extensive commercial usage means there is a wide variety of existing components. Fiber optics are essentially immune to Electromagnetic Interference (EMI), and provide faster signal propagation. Optical fiber is also significantly lighter than copper cabling, which leads to large cost reductions for fuel. Each technology is preferred for different applications on LOP–G.

The use of fiber optic and copper wire GbE implies a converter that can seamlessly facilitate communications within LOP–G. This converter would have to meet timing requirements outlined in IEEE 802.3ay clauses 38/39 and SAE AS6802, operate off the LOP–G power rails in a variety of environments, withstand EMI and Electrostatic Discharge (ESD), and have a minimal SWaP footprint.

Design

The prototype converter supports the following GbE technologies:

- 1000BASE–CX copper GbE
- 1000BASE–SX fiber optic GbE

The design has the following specifications:

- Convert bidirectionally between each GbE technology
- Operate on 28 V power rail
- Tolerate up to ±4 V variance on power rail
- Survive over–voltage power surges up to 12 V
- Minimize SWaP
- Use mostly Commercial Off–the–Shelf (COTS) components
- Meet timing requirements summarized by **Fig. 1**.

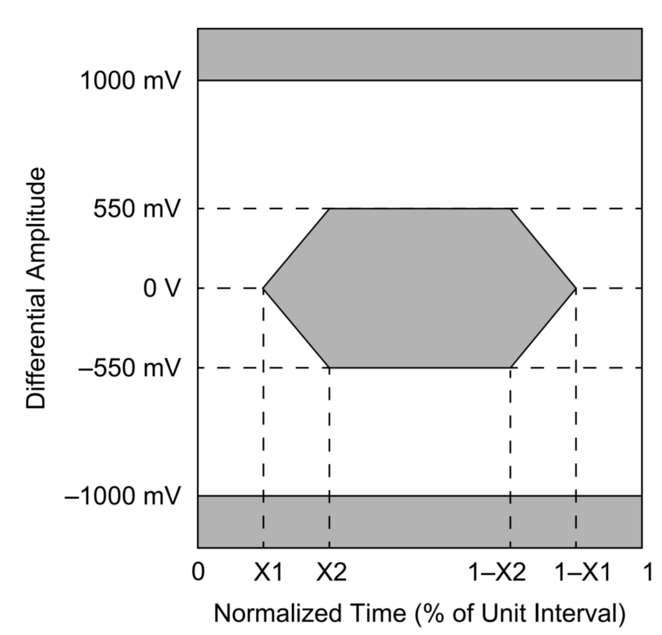

Figure 1. Eye diagram mask for 1000BASE–CX, taken from IEEE 802.3ay Fig. 39–4. X1 is 0.14 and X2 is 0.34.

The final design used the following components:

Component	Class	Quantity	Subtotal (USD)
TRACO TMR 2410	COTS components	1	$16.05
PulseR TM1250HSB5		1	$72.85
Avago HFBR5911LZ		1	$52.50
Amphenol quadrax receptacle	Connectors, PCB	1	$262.71
Mini–Fit connector		2	$1.14
PCB		1	$66.00
Resistors (various)	Size 1206 SMD components	11	$2.57
Capacitors (various)		6	$7.13
LEDs (green)		2	$0.68
Total Cost			$481.66

Table 1. Cost and components of converter prototype.

The design circuitry and PCB layout are shown in **Figs. 2–3**.

Design (cont'd)

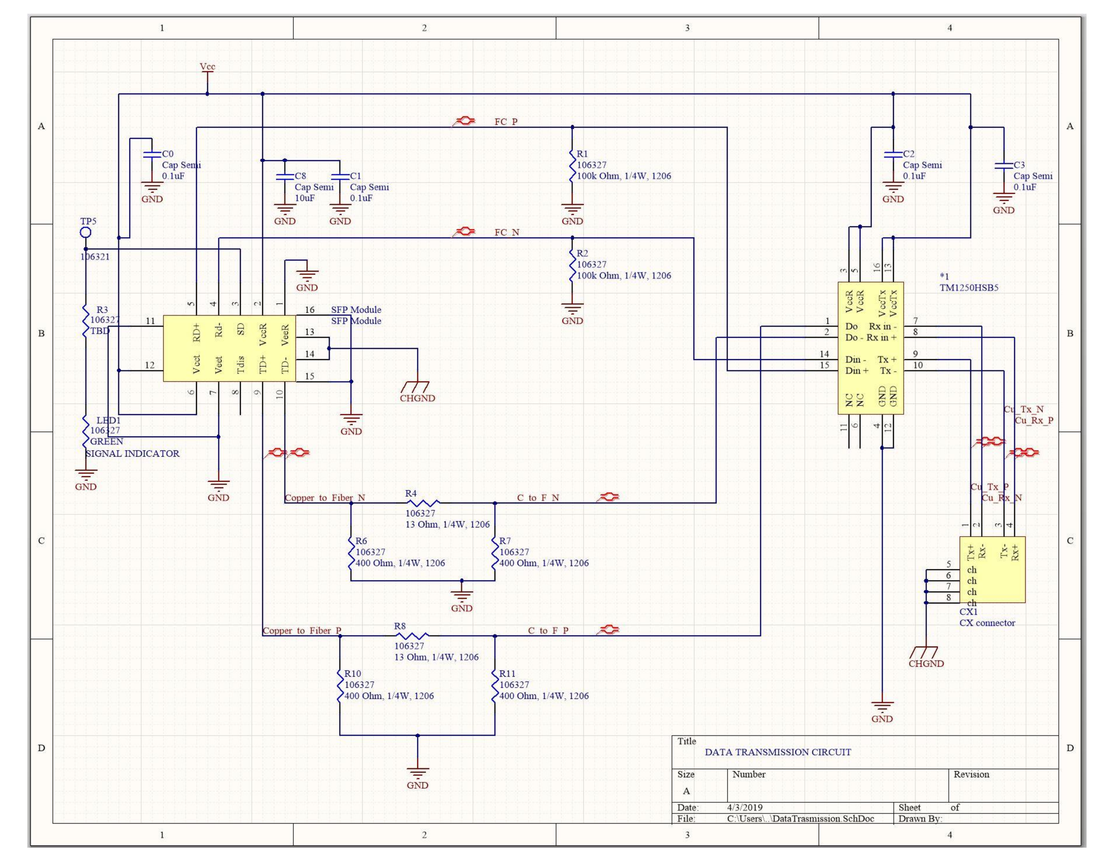

Figure 2. Signal conversion schematic, including signal attenuation on data lines between LVPECL and CML portions

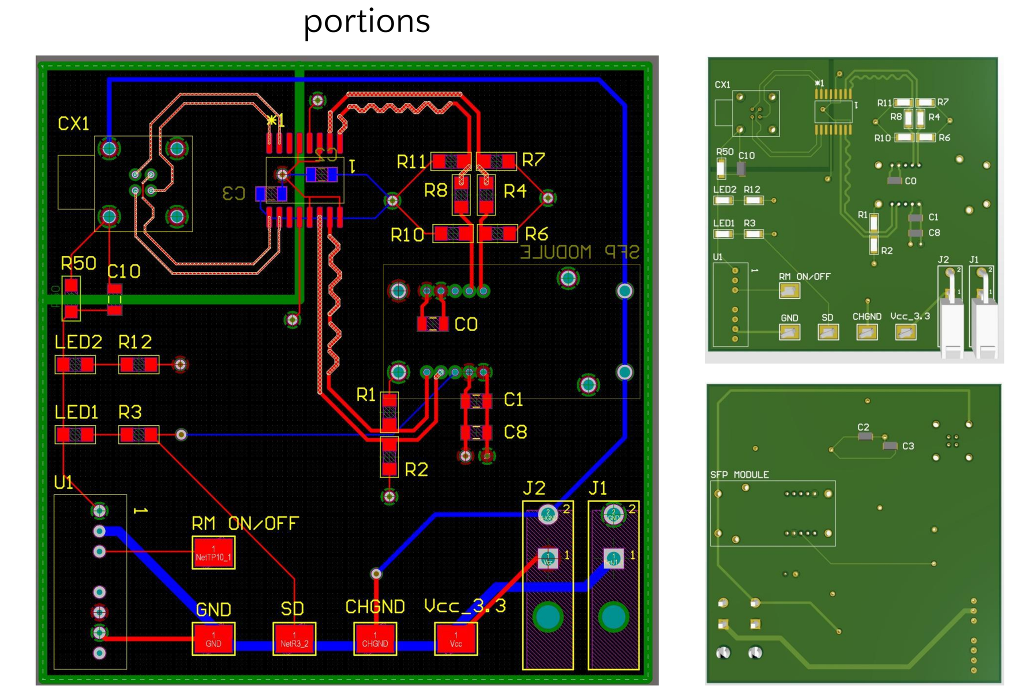

Figure 3. The (left) PCB layout, and the simulated (right, top) front view and (right, bottom) back view.

Testing and Results

The prototype underwent testing and was shown to be functional, with the following results:

1. The prototype was given external voltages from 24 V to 32 V, and the board's supply voltage was checked (expected value: 3.3 V). The result was a steady 3.296 V supply voltage.
2. A ping was sent from a computer through the copper terminal of the converter to another computer. The reply was sent back through the fiber optic terminal (expected output: ping reply received). The prototype translated the signals bidirectionally, seen in **Fig. 4**.

Testing and Results (cont'd)

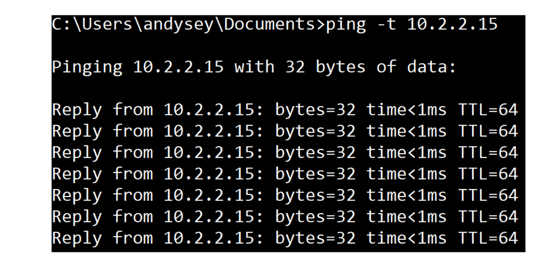

Figure 4. Successful conversions indicated by ping response.

3. The prototype's copper output was connected to a digital serial analyzer and the resulting eye diagram was compared to the eye mask in **Fig. 1**. The result was a clean data eye that fit in the mask (see **Fig. 5**).

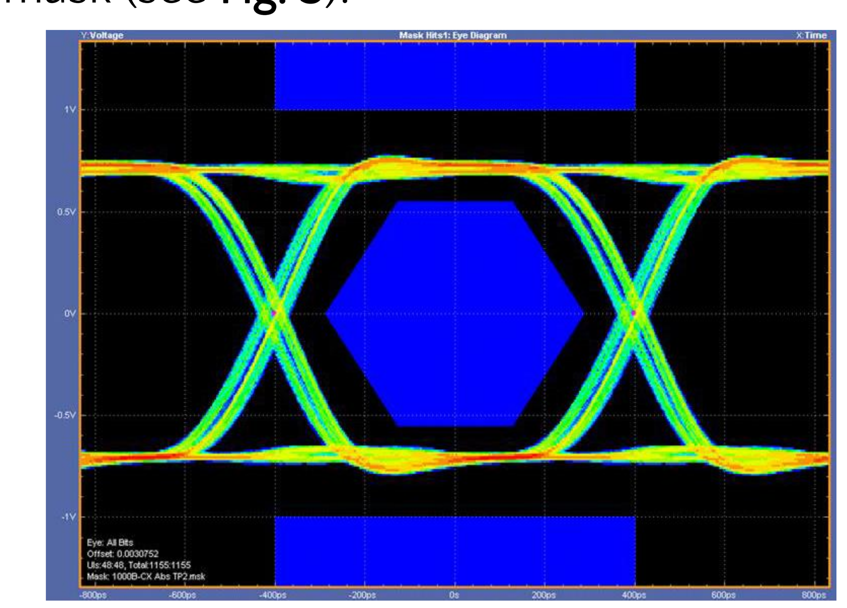

Figure 5. Data eye diagram compared to eye mask from IEEE 802.3ay.

Future Steps

The following will bring the design to full flight functionality:

- Add support for other GbE technologies
- Add further front–end protection from EMI and long–term damage:
  - EMI filter
  - Inrush current limiter
  - Transient voltage suppressor
- Add Faraday cage enclosure
- Increase operational temperature range

References

[1] T. Bonk, "NASA DSG," Honeywell Aerospace, 2018. [PowerPoint slides].
[2] NASA, "Advanced Space Transportation Program: Paving the Highway to Space," National Aeronautics and Space Administration. [Online]. Available: https://www:nasa:gov/centers/marshall/news/background/facts/astp:html. [Accessed 11 Oct. 2018].
[4] IEEE, "Ethernet Access Method and Physical Layer Specifications," IEEE Std. 802.3ay, Institute of Electrical and Electronics Engineers, Dec. 2008.
[5] SAE, "Time–Triggered Ethernet," SAE Std. AS6802, SAE Aerospace, Nov. 2016.
[6] PulseR Ruggedized Solutions, "High Speed Serial Transceiver Line Interface Module," TM1250HSB5 datasheet, Jan. 2019.
[7] J. M. Senior, "Optical Fiber Communications Principles and Practice", 2nd ed. New Jersey: Prentice Hall, 1992.