Versatile transceiver and transmitter production status

J. Troska, a,1 S. Détraz, a L. Olanterä, a S. Seif El Nasr-Storey, a,b C. Sigaud, a C. Soós a and F. Vasey a

a CERN, 1211 Geneva 23, Switzerland 
b University of Bristol, Bristol BS8 1TL, U.K.

E-mail: jan.troska@cern.ch

ABSTRACT: Production of the Versatile transceiver and twin transmitter modules for use in the readout and control systems of upgrading LHC detector systems is starting. We review the performance of the prototypes produced so far and show that the modules are ready for production. We outline the commercial actions being taken to procure parts and assemblies and show the production plan for delivering known good parts in the various flavours required for the upgrade projects that will be using them.

KEYWORDS: Optical detector readout concepts; Radiation-hard electronics; Front-end electronics for detector readout

1 Corresponding author.
1 Introduction

The Versatile Link project [1] aims to develop the optoelectronic components required to build a 5 Gb/s, bi-directional, radiation hard optical link that bridges the 50–150 m distance between the front-end of the upgraded detectors at the HL-LHC and the back-ends located in the shielded counting rooms. An overview of the Versatile Link system is shown in figure 1. The link will support optical systems operating at either 850 nm and 1310 nm wavelength over multimode and singlemode optical fibres respectively. The Versatile link project is closely linked to the Gigabit Transceiver (GBT) [2] chip-set design project which aims to develop the ASICs needed to drive the optical components qualified in the framework of the Versatile Link project.

The Versatile Link project was started jointly by ATLAS and CMS in 2008. It developed and qualified components for LHC experiments upgrades with two grades of radiation resistance: Tracker-grade and Calorimeter-grade. However, as it became clear that the timescale for the upgrades of the ATLAS and CMS trackers was shifting beyond 2020, only the Calorimeter-grade option was continued to the pre-production readiness stage. Thus, we refer here only to Calorimeter-grade Versatile Links as envisaged for use in the phase I upgrades of ATLAS, CMS and LHCb. The radiation tolerance levels for this Calorimeter grade require that the components must withstand 10 kGy total dose and \(5 \times 10^{14}\) neutrons/cm\(^2\).

![Figure 1. Overview of the Versatile Link system showing the components of the VTRx.](image)
2 Versatile Transceiver and Twin Transmitter module

In order to enable the use of the Versatile Link in systems that have installed fibre-plants of both single-mode and multi-mode type, three module types have been developed:

- Singlemode transceiver VTRx, based on Fabry-Pérot Edge-Emitting laser diode and InGaAs Photodiode
- Multimode transceiver VTRx, based on VCSEL and GaAs Photodiode
- Multimode dual transmitter VTTx, based on VCSELs

All modules have been built with radiation-tolerant by design ASICs sourced from the GBT project: GBLD laser driver [3] and GBTIA photodiode amplifier [4]. The laser and photodiode have been chosen from commercially available parts qualified to withstand the specified radiation tolerance levels [5].

3 Functional evaluation

The full functionality of the various VTTx and VTRx module flavours was demonstrated in 2012 for room temperature operation [6]. It remained to show that the performance is maintained over the specified operating temperature range from $-30^\circ\text{C}$ to $+60^\circ\text{C}$. We have noted that the lowest operational temperature specification for the Versatile Link comes essentially from users from upgrading Tracking systems in CMS and ATLAS, an upgrade which will not come until the Phase II
rise and fall times are in Figure 22 and the jitter values in Figure 23. Also the eye height is more reduced in the case of v5 at high temperatures: GBLD v4.1 meets the rise time specification of 70 ps, but at the same time fall times are still above the v4.1. Rise times are shorter with small bias and modulation currents (4 mA), when v5 even shows prototypes of both SM and MM ROSAs meeting the sensitivity specification required for use in Versatile Link Systems.

4 Production plan

Table 1 summarizes the requirements that have been communicated to date by the ATLAS, CMS, and LHCb collaborations for Phase-2 upgrades to various parts of their detectors. The ALICE collaboration is also actively pursuing the option of using the Versatile Link system in its upgraded readout and control system. The latter quantities are to be confirmed early in 2014 and will add between 30% to 50% to the overall quantity of VTTx and VTRx. The overall cost of production of all modules as indicated to date is estimated to be close to 2.3 MCHF. Final pricing is expected to be confirmed early in 2014 once all component vendors have been chosen. Production of all
Two devices were tested using higher data-rates in order to gain an impression of the performance limits. At high data-rates the performance is limited by the transimpedance amplifier (TIA). Figure 5 shows the BER curves of devices 2K35268 and 23K5272 using the PIN responsivity of 0.7 A/W reported on the photodiode datasheet.

The BER curves are shown in Figure 3. The sensitivity at BER = 10^-12 is -16.3 dBm. The results using multi-mode versions are similar to single mode results, except that the PIN responsivity of 0.35 A/W reported on the photodiode datasheet.

The minimum input current amplitude at GBTIA and the minimum responsitivity of the single-mode DUTs measured at 1310 nm. The expected minimum sensitivity calculated was -15.3 dBm, and calculated expected minimum sensitivity of -13.7 dBm. There is however a deviation in the electrical output eye diagrams, Figure 8. All devices behave similarly and according to the specifications. Like during the single-mode tests, the devices operate well with a small power penalty up to 6 Gbps, but with higher data-rates the power penalty is significant due to the limitations of the TIA.

The results are in-line with both manufacturer’s sensitivity values, ranging from -14.9 to -15.3 dBm. The power penalty at 10 Gbps is 4 dBm for both single-mode and multi-mode devices, and the expected minimum sensitivity is -13.3 dBm.

Table 1. Overview of required quantities as presently requested by various users.

| User       | TOSA | ROSA | Latch | VTRx | VTTx |
|------------|------|------|-------|------|------|
| LHCb       | 16900| 2900 | 9900  | 2900 | 7000 |
| HCAL       | 4400 | 400  | 2400  | 400  | 2000 |
| ATLAS SmWh | 1850 | 650  | 1250  | 650  | 600  |
| ATLAS LArg | 150  | 150  | 150   | 150  |      |
| Totals     | 200  | 2300 | 4100  | 200  | 9600 |

The results are shown in Figure 6. The Bit Error Rate curves showing GBTIA performance.

| Component | OMA [dBm] |
|-----------|-----------|
| Single-mode ROSA | -15.3 dBm |
| Multi-mode ROSA | -13.7 dBm |

The measurements show that the results are consistent with the expected minimum sensitivity.

Each component will go through a pre-production qualification phase before the go-ahead is given to full production. The VTRx and VTTx modules will be subject to a 100% functional test using a production test setup being prepared by CERN that will be present in the company doing the module assembly throughout production. Lot acceptance will be carried out during production to ensure a constant high level of quality. Ageing tests will be carried out on components and full assemblies, starting during the pre-production phase.

5 Quality Assurance plan

Versatile Transceiver and Twin Transmitter modules are ready for production. The circuit and mechanical design of the modules is complete and has been shown to operate with specified limits in all expected environments. We have shown that the effect of temperature on the sensitive element of the module (the transmitter) is manageable and that the receiver operates with sufficient sensitivity. Production quantities have been communicated to us by the system designers of ATLAS, CMS, and LHCb that wish to deploy Versatile Link systems in their Phase I upgrades for installation after 2017. The outline production plan shown here is compatible with these deployments as VTRx and
VTTx modules will start to become available in larger quantities in the second half of 2014 with production being complete in the first half of 2015. Prototypes are currently available to interested users for use in system demonstrators together with the list of back-end components suitable for use in Versatile Link systems. In addition, an Application Note is available [7] to guide system design.

Acknowledgments

The authors would like to graciously acknowledge the support of the EU-funded 7th Framework Marie-Curie ACEOLE programme.

References

[1] L. Amaral et al., The Versatile Link, a common project for super-LHC, 2009 JINST 4 P12003.

[2] P. Moreira, A. Marchioro and K. Kloukinas, The GBT: A proposed architecture for multi-Gb/s data transmission in high energy physics, in Proceedings of TWEPP 2007, the Topical Workshop on Electronics for Particle Physics, CERN-2007-007 (2007).

[3] G. Mazza et al., A 5 Gb/s Radiation Tolerant Laser Driver in 0.13 μm CMOS technology, in Proceedings of TWEPP 2009, the Topical Workshop on Electronics for Particle Physics, CERN-2009-006 (2009).

[4] M. Menouni, P. Gui and P. Moreira, The GBTIA, a 5 Gbit/s Radiation-Hard Optical Receiver for the SLHC Upgrades, in Proceedings of TWEPP 2009, the Topical Workshop on Electronics for Particle Physics, CERN-2009-006 (2009).

[5] J. Troska et al., Laser and photodiode environmental evaluation for the versatile link project, 2013 JINST 8 C02053.

[6] C. Soós et al., Versatile transceiver development status, 2012 JINST 7 C01094.

[7] F. Vasey et al., The Versatile Link Application Note, http://cern.ch/go/V8qd (2013).