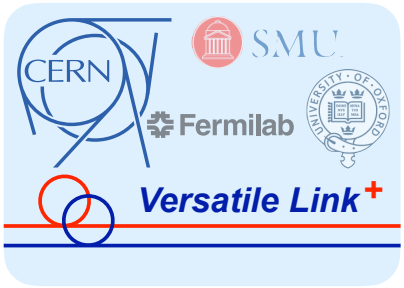

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Versatile Link+ Technical Specification, part 2.1

Versatile Link+ Transceiver (VTRx+)

Abstract

This document describes the mechanical, electro-optic, and environmental specifications of the front-end Transceiver module for use in the Versatile Link+ common project for optical data transmission in HL-LHC detectors.

Prepared by	*Checked by*	*Approved by*
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Document History

Rev. No	*Date*	*Pages*	*Description of Changes*
1.0	3 Mar. 2017	*All*	First Version
1.1	30 May 2017		Document brought in line with System Specification
1.2	24 July 2017		Added module variants with different heights
1.3	4 August 2017	*5*	Updated introductory text for clarity
		7,8	Updated Tables 2, 3 & 4 with TBD/C on various entries
		9	Changed jitter specifications to only be the jitter added by the VTRx+ module
		10	Added Glossary
1.4	13 December 2017	*8,9*	Updated connector pinout & description
1.5	8 May 2018	*8,9*	Added mating connector information
1.6	27 November 2018	*3,6-8,10*	Updated spec tree, power consumption, Tx transition times. Added mechanical outline drawing and updated 3D view.
1.7	13 December 2018	*10*	Added maximum input OMA for Rx.
1.8	16 January 2019	*7,9*	Added min fibre bend radius, Thermistor info.
1.9	3 July 2019	*9*	Updated pinout.
1.10	14 August 2019	*5,7,11,12,13*	Various updates.
2.0	17 August 2019	*all*	Various updates.
2.1	8 October 2019	*5,8,10,12*	minor comments from FV, added fibre pinout.
2.2	10 February 2020	*7*	updated pigtail spec.
2.3	24 March 2020	*7*	updated pinout to reflect that in production version Thermistor is 1k NTC.
2.4	24 April 2020	*10,11*	Added Eye Mask information.
2.5	9 March 2021	*5,6,9*	Updated Introduction, Section 1 and reference for I2C Control information.
2.6	18 March 2021	*15*	Updated units in Thermistor table in Appendix.
2.7	24 September 2021	*15*	Added explicit I2C address.
2.8	15 March 2022	*15*	updated labelling & packaging info.
2.9	1 July 2022	*8*	updated power consumption.
2.10	7 June 2023	*8*	updated differential input to match LDD spec.

Specification Tree

The hierarchy of Versatile Link+ specifications is shown below. The position of the present specification document is highlighted in bold. Line items in italic will not result in specification documents but are shown to ease understanding of the structure.

EDMS Document Number

Contents

Introduction

The Versatile Link+ (VL+) project [1] aims to provide a multi-gigabit per second optical physical data transmission layer for the readout and control of High Luminosity LHC (HL-LHC) experiments. A point-to-point bidirectional system architecture is proposed as shown in figure 1.

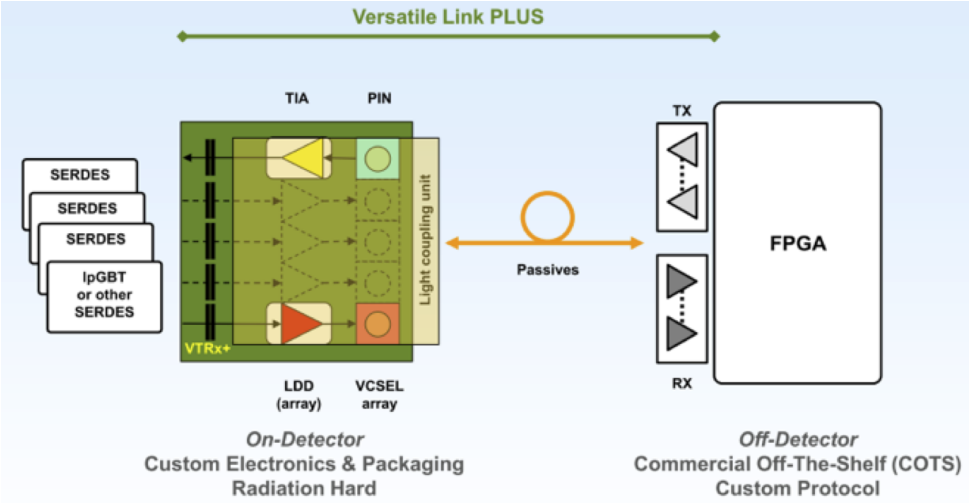

Figure 1: Versatile Link+ (VL+) Architecture.

The link operation is described in Part 1: System specification, while link components have their dedicated specification in Part 2: Components. This document, Part 2.1: Versatile Link+ Transceiver, describes the specifications and environmental requirements for the front-end Versatile Link+ transceiver (VTRx+) modules. The VL+ front-end components are placed on detector, at the front-end, and are therefore subjected to the harshest environmental conditions and must be capable of reliable operation under those conditions.
The VTRx+ modules contain the following custom developed or qualified parts (Tx = transmitter, Rx = receiver, TRx = transceiver):

1. VCSEL laser diode array or single die(Tx)
2. Radiation tolerant laserdriver ASIC in quad-channel format (Tx).
3. PIN diode single die (Rx)
4. Radiation tolerant transimpedance amplifier (TIA) in single-channel format (Rx).

The link supports multi-mode (MM) operation with a center-wavelength of 850nm. The fiber cables are commercial laser optimized MM fibers, with a radiation resistant section inside the detector if required by the final application. All VTRx+ modules will have a radiation-hard pigtail regardless of final application.
The link is naturally bi-directional. However, matching the number of front-end to back-end (uplink) and back-end to front-end (downlink) transmissions is not a requirement since the VTRx+ module always contains four transmitters and one receiver. It is however possible to use the modules as, for example multi-channel front-end transmitters (i.e. 4 Tx only) or single-channel front-end transceivers (i.e. 1 Tx & 1 Rx), by disabling unused channels. By default, at power-up, only Tx channel 1 is active, the others are disabled.

1 General Specifications

Table 1: VTRx+ module general specifications.

#	Specification	Min.	Typ.	Max.	Unit
1.1.1	Upstream (Tx) Datarate	5.12		10.24	Gb/s
1.1.2	Number of Upstream Channels[a]	1		4	
1.2.1	Downstream (Rx) Datarate		2.56	5.12[b]	Gb/s
1.2.2	Number of Downstream Channels			1	

[a] Only Tx channel 1 is active at power-up, the others need to be enabled via I2C.
[b] At start of life. Irradiation will degrade the absolute maximum so that at end of life after highest tolerated radiation level the maximum is equivalent to the typical start of life value.

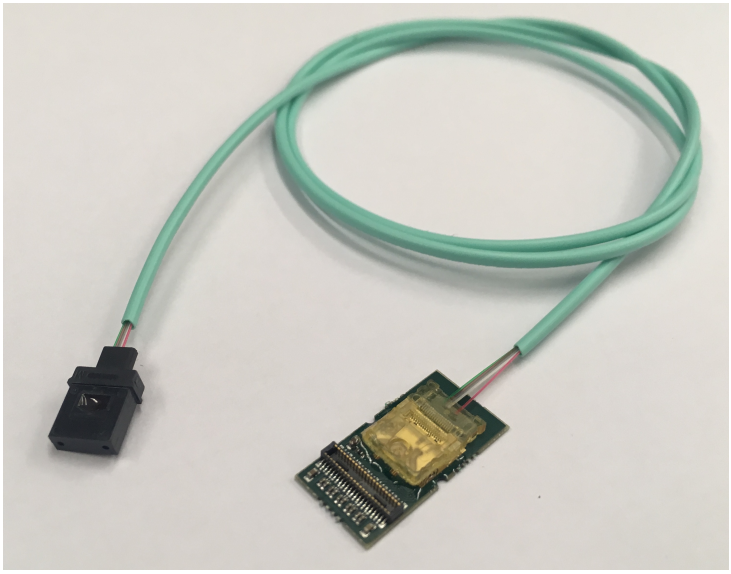

Figure 2: Photo of VTRx+module showing module, pigtail, and MT connector.

2 Mechanical Specifications

Table 2: VTRx+ module mechanical specifications.

#	Specification	Min.	Typ.	Max.	Unit
2.1.1	Length			20	mm
2.1.2	Width			10	mm
2.1.3	Height			2.5	mm
2.1.4	Mass		5		g
2.2.1	Material		Non-magnetic, Low-Z		
2.3.1	Optical Interface		Pigtail		
2.3.2	Pigtail length[a]	200[b]		1000[b]	mm
2.3.3	Connector type on Pigtail		MT female		
2.3.4	Pigtail type		Loose Tube Round Cable		
2.3.5	Pigtail bending radius[1]	7.5[c]	15[d]		mm
2.3.6	Pigtail Outer Diameter	1.0	1.1	1.2	mm
2.3.7	Pigtail Colour		Blue RAL 5015[b]		
2.3.8	Pigtail Material		Low Smoke Halogen Free Polymer		

[a] Number of different pigtail lengths is 5 to 10 (TBC).
[b] TBC.
[c] For mechanical reliability, loss per 2 turns <0.2 dB.
[d] For loss per 2 turns <0.1 dB.

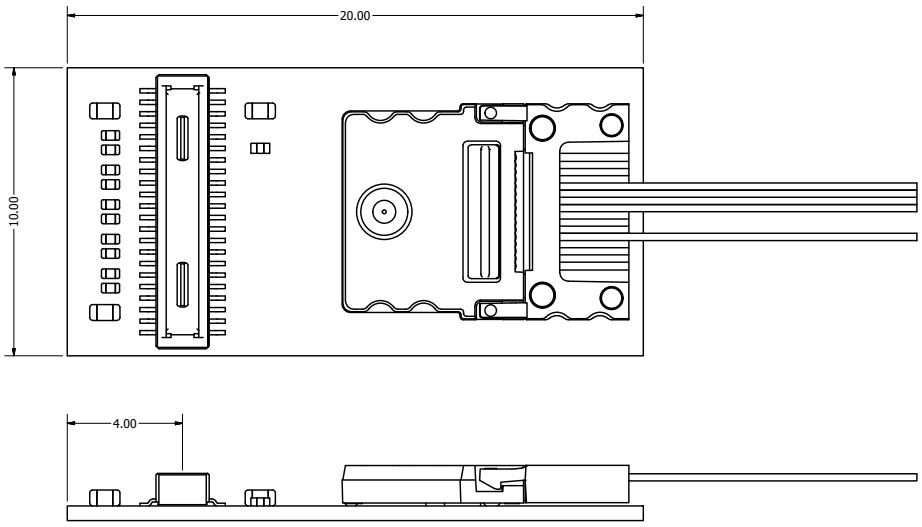

Figure 3: Mechanical outline drawing.

3 Electrical Interface Specifications

Table 3: VTRx+ module electrical interface specifications.

#	Specification	Min.	Typ.	Max.	Unit
3.1.1	Number of pins			40	
3.1.2	Connector Type[a]		*Hirose DF40-C-40DP-0.4V*		
3.2.2	Supply Voltage Rx 2V5	2.25	2.5	2.75	V
3.2.3	Supply Current Rx 2V5		40		mA
3.2.2	Supply Voltage Tx 2V5	2.25	2.5	2.75	V
3.2.3	Supply Current Tx 2V5[b]		4 + 13/ch		mA
			15/ch[c]		mA
3.3.4	Supply Voltage 1V2	1.1	1.2	1.3	V
3.3.5	Supply Current 1V2		4 + 12/ch		mA
Total Power (Informative, default settings, nominal voltage, TBC)					
	1 Tx & 1 Rx Module		15		mA on VCCT1V2
			20		mA on VCCT2V5
			50		mA on VCCR2V5
	2 Tx & 1 Rx Module		27		mA on VCCT1V2
			32		mA on VCCT2V5
			50		mA on VCCR2V5
	3 Tx & 1 Rx Module		38		mA on VCCT1V2
			43		mA on VCCT2V5
			50		mA on VCCR2V5
	4 Tx & 1 Rx Module		50		mA on VCCT1V2
			55		mA on VCCT2V5
			50		mA on VCCR2V5
	4 Tx Module		50		mA on VCCT1V2
			55		mA on VCCT2V5
3.4.1	I2C address	0x50 (7-bit address 0b1010000)			

[a] Mating connector for overall mated height = 2.5 mm is Hirose DF40C-2.0-40DS-0.4V
[b] Tx current consumption is per active channel. By default only one channel is active at power-up.
[c] Estimated maximum current consumption at End Of Life in highest radiation environment.

Table 4: VTRx+ module pin numbering and description.

Pin #	Name	Description	Pin #	Name	Description
1	VCCR2V5	2.5V Power supply for TIA	2	n/c	
3	VCCR2V5	2.5V Power supply for TIA	4	RSSI	RSSI current output from TIA[a]
5	GND	Ground	6	GND	Ground
7	RXN	Rx $\overline{\text{output}}$	8	SDA	I2C[b] data (to be terminated to VCCT1V2)
9	RXP	Rx output	10	SCL	I2C[b] clock (to be terminated to VCCT1V2)
11	GND	Ground	12	GND	Ground
13	TX1N	Tx Ch.1 $\overline{\text{input}}$	14	RSTN	Laser Driver Reset
15	TX1P	Tx Ch.1 input	16	DIS	Laser Driver Disable
17	GND	Ground	18	GND	Ground
19	TX2N	Tx Ch.2 $\overline{\text{input}}$	20	n/c	
21	TX2P	Tx Ch.2 input	22	n/c	
23	GND	Ground	24	GND	Ground
25	TX3N	Tx Ch.3 $\overline{\text{input}}$	26	n/c	
27	TX3P	Tx Ch.3 input	28	n/c	
29	GND	Ground	30	GND	Ground
31	TX4N	Tx Ch.4 $\overline{\text{input}}$	32	TH1	1k Thermistor Terminal 1[c,d]
33	TX4P	Tx Ch.4 input	34	TH2	1k Thermistor Terminal 2[c,d]
35	GND	Ground	36	GND	Ground
37	VCCT2V5	2.5V Power supply for Laser Driver	38	VCCT1V2	1.2V Power supply for Laser Driver
39	VCCT2V5	2.5V Power supply for Laser Driver	40	VCCT1V2	1.2V Power supply for Laser Driver

[a] RSSI pin must be pulled up to VCCR2V5.
[b] I2C register map can be found in Laser Driver Specification[2].
[c] Prototype units had 10k Thermistors.
[d] Murata NCP03XM102E05RL, see Appendix 1.

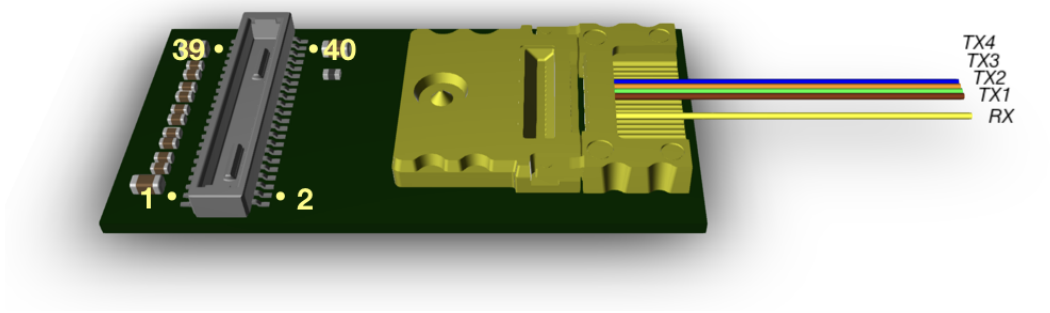

Figure 4: Module sketch showing pin numbering.

4 Electro-Optical Specifications

Table 5: VTRx+ module electro-optical specifications.

#	Specification	Min.	Typ.	Max.	Unit
4.1.1	Tx OMA	-5.2			dBm
4.1.2	Tx Extinction Ratio	3			dB
4.1.3	Tx Eye Opening	60			%[a]
4.1.4	Tx rise/fall time[b]			44	ps
4.1.5	Tx Total Jitter[c,d]			25	ps
4.1.6	Tx Deterministic Jitter[e]			12	ps
4.1.7	Tx Output Eye Mask	*see Table 6 & Figure 5*			
4.1.8	Tx output wavelength	840	850	860	nm
4.2.1	Tx Differential input voltage	200		1200	mV
4.2.2	Tx Input rise/fall time[b]		30	40	ps
4.2.3	Tx Input Total Jitter[c]			0.26	UI
4.2.4	Tx Input Deterministic Jitter			0.14	UI
4.2.5	Tx Input Eye Mask	*see Table 6 & Figure 6*			
4.2.6	Tx Differential input impedance	90	100	110	Ω
4.3.1	Rx input Total Jitter[c]			0.48	UI
4.3.2	Rx input Deterministic Jitter			0.28	UI
4.3.3	Rx Sensitivity[c]			-13.1	dBm
4.3.4	Rx input wavelength	840		860	nm
4.3.5	Rx input OMA			2.0	dBm
4.3.6	Rx input AOP			2.4	dBm
4.4.1	Rx Differential output voltage	200		600	mV
4.4.2	Rx rise/fall time[b]			40	ps
4.4.3	Rx Total Jitter[c,f]			34	ps
4.4.4	Rx Deterministic Jitter[g]			14	ps
4.4.5	Rx Eye Mask	*see Table 6 & Figure 6*			

[a] Eye Opening is a fraction of OMA.
[b] 20-80%
[c] at BER = 1×10^{-12}.
[d] Output of VL+ up to this point is 0.44 UI (at 10.24 Gb/s).
[e] Output of VL+ up to this point is 0.26 UI (at 10.24 Gb/s).
[f] Output of VL+ up to this point is 0.175 UI (at 2.56 Gb/s).
[g] Output of VL+ up to this point is 0.105 UI (at 2.56 Gb/s).

Table 6: VTRx+ Eye Mask Parameters.

#	Specification	X1	X2	X3	Y1	Y2	Y3
4.1.7	Tx Output Eye Mask	22.5	33.2	42	0.27	0.35	0.40
	Unit	ps	ps	ps	Norm.	Norm.	Norm.
	(UI = 97.66 ps)				Amp.	Amp.	Amp.
4.2.5	Tx Input Eye Mask	10.7	30.3		95	350	
	Unit	ps	ps		mV	mV	
	(UI = 97.66 ps)						
4.4.5	Rx Output Eye Mask	28.3	48.8		95	350	
	Unit	ps	ps		mV	mV	
	(UI = 390.6 ps)						

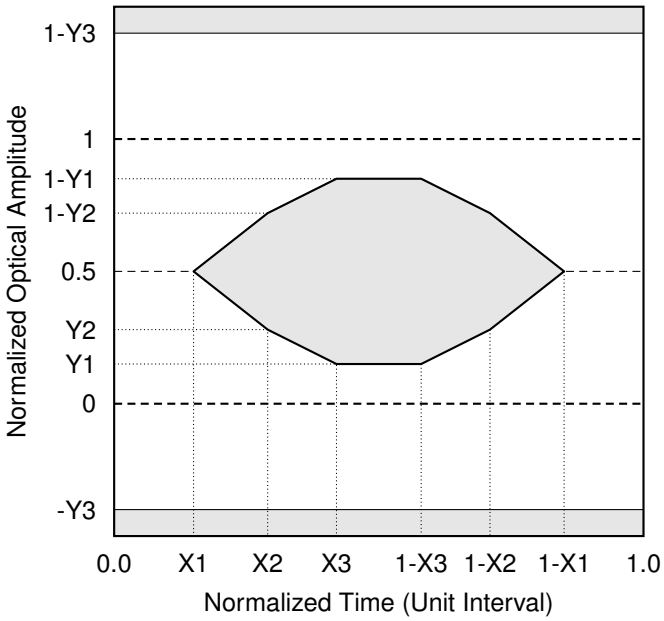

Figure 5: Optical Eye Mask for 4.1.7 Tx Output

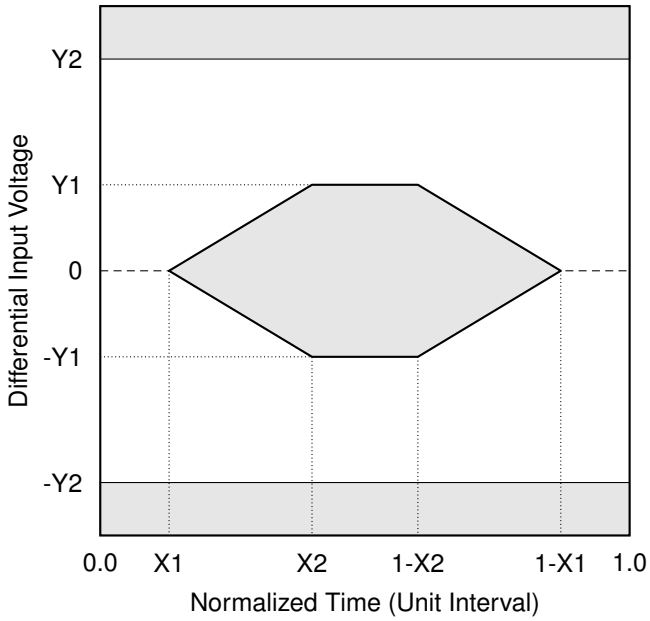

Figure 6: Electrical Eye Mask for 4.2.5 Tx Input & 4.4.5 Rx Output

5 Environmental Specifications

Table 7: VTRx+ module environmental specifications.

#	Specification	Min.	Typ.	Max.	Unit
5.1.1	Total Ionising Dose			1	MGy
5.1.2	Total Neutron Fluence[a]			1×10^{15}	cm^{-2}
5.1.3	Total Hadron Fluence[a]			1×10^{15}	cm^{-2}
5.2.1	Operating Temperature[b]	-35		+60	℃
5.3.1	Magnetic Field			4	T

[a] The radiation qualification will be carried out in a beam facility providing neutrons with a mean energy of 20 MeV, where both of the above total fluence conditions are simulated by exposure to 3×10^{15} neutrons/cm^2.
[b] Ambient temperature.

6 Optical Interface Specifications

Table 8: VTRx+ module optical interface specifications.

#	Specification	Min.	Typ.	Max.	Unit
6.1.1	Optical Fibre Type		Prysmian SRH Multimode		
6.2.1	Optical Connector Type		MT12[a]		

[a] The MT connector is always female when delivered. Guide pins are added just before connection with another MT connector[3].

Table 9: VTRx+ module optical interface pinout.

VTRx+ Function	Fibre Number
RX	7
TX1	6
TX2	5
TX3	4
TX4	3

7 Labelling

VTRx+ modules will be individually labelled using a 2D Data matrix code and a human readable serial number. The Data matrix code contains 13 Alphanumeric characters: XXXXXXXYYYYYY; where XXXXXXX is the manufacturing product code identical for all modules ”0016611”; and YYYYYY is a six-digit unique serial number in the range [000000-999999]. YYYYYY is then also marked in human-readable form.
The code will be marked directly onto the VTRx+ PCB as shown in figure 7, making it machine readable using a suitable high performance barcode reader[1]. The high density of the code and poor contrast of the engraving on the PCB means that typical smartphone cameras are not able to read the code.
The label sizes are as follows:

- Serial number size: 1.0 mm by 5.0 mm
- Data matrix size: 3.0 mm by 3.0 mm

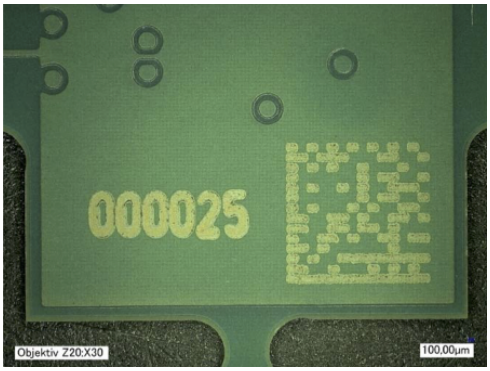

Figure 7: VTRx+ module labels.

[1] An example of a suitable reader is the Honeywell 1950 HD series or any other reader capable of reading DPM (Direct Part Mark) codes.

8 Packaging

VTRx+ modules will be packaged in individual plastic blister packages that will placed in an antistatic bag(figure 8). A number (up to 30, TBC) of such bags will be packed inside cardboard boxes for shipment.

Figure 8: Individually packaged VTRx+ module.

References

References

[1] Versatile Link Plus Project Team. VLPlus Specification Part 2.3: Optical Fibre. https://edms.cern.ch/document/2045619.

[2] Versatile Link Plus Project Team. Versatile link plus technical specification, part 2.1.3: Laser driver. https://edms.cern.ch/document/1719330.

[3] USConec AEN-1910. Instructions for mating MT ferrules when using a spring clamp device. http://www.usconec.com/resources/AEN/AEN-1910.pdf.

Glossary

AOP	Average Optical Power
OMA	Optical Modulation Amplitude
Rx	Receiver
TBC	To Be Confirmed
TBD	To Be Defined
Tx	Transmitter
TRx	Transceiver (Transmitter & Receiver)
UI	Unit Interval

Appendix 1: NTC Thermistor Specifications

Information retrieved on 24 April 2020 from
`https://www.murata.com/products/productdata/8796839411742/NTHCG41.txt?1437969936000`

Parameter	Value	Unit	Tolerance
R25	1.0	kΩ	± 3 %
B(25/50)	3500	K	± 1 %
B(25/100)	3560	K	± 1 %

The temperature T (in °C) of the thermistor can be calculated from its resistance R, the reference resistance R25, and the coefficient B(25/100) using the following equation:

$$T = \frac{1}{ln(\frac{R/R25}{B})} + \frac{1}{298.15} - 273.15$$

Temp ℃	R-low kΩ	R-mid kΩ	R-high kΩ	Temp ℃	R-low kΩ	R-mid kΩ	R-high kΩ	Temp ℃	R-low kΩ	R-mid kΩ	R-high kΩ
-40	20.0072	21.2663	22.5842	16	1.3841	1.4320	1.4803	71	0.1963	0.2056	0.2152
-39	18.9334	20.1137	21.3484	17	1.3292	1.3747	1.4205	72	0.1904	0.1995	0.2088
-38	17.9234	19.0302	20.1872	18	1.2769	1.3201	1.3634	73	0.1847	0.1936	0.2027
-37	16.9730	18.0112	19.0956	19	1.2269	1.2678	1.3090	74	0.1792	0.1879	0.1968
-36	16.0783	17.0524	18.0693	20	1.1791	1.2180	1.2570	75	0.1739	0.1823	0.1910
-35	15.2357	16.1500	17.1038	21	1.1335	1.1704	1.2074	76	0.1688	0.1770	0.1855
-34	14.4372	15.2953	16.1898	22	1.0898	1.1249	1.1600	77	0.1638	0.1719	0.1802
-33	13.6852	14.4907	15.3298	23	1.0481	1.0814	1.1147	78	0.1590	0.1669	0.1750
-32	12.9765	13.7330	14.5204	24	1.0082	1.0398	1.0714	79	0.1544	0.1621	0.1700
-31	12.3086	13.0192	13.7583	25	0.9700	1.0000	1.0300	80	0.1499	0.1574	0.1652
-30	11.6788	12.3465	13.0405	26	0.9327	0.9619	0.9912	81	0.1456	0.1529	0.1605
-29	11.0818	11.7091	12.3608	27	0.8971	0.9255	0.9540	82	0.1414	0.1486	0.1560
-28	10.5187	11.1083	11.7204	28	0.8629	0.8907	0.9185	83	0.1374	0.1444	0.1516
-27	9.9875	10.5418	11.1168	29	0.8303	0.8573	0.8844	84	0.1335	0.1403	0.1474
-26	9.4861	10.0074	10.5478	30	0.7991	0.8253	0.8517	85	0.1297	0.1364	0.1433
-25	9.0127	9.5030	10.0110	31	0.7692	0.7948	0.8205	86	0.1261	0.1326	0.1394
-24	8.5638	9.0250	9.5025	32	0.7406	0.7655	0.7906	87	0.1226	0.1290	0.1356
-23	8.1398	8.5738	9.0228	33	0.7132	0.7375	0.7619	88	0.1192	0.1254	0.1319
-22	7.7392	8.1477	8.5700	34	0.6869	0.7106	0.7344	89	0.1159	0.1220	0.1283
-21	7.3606	7.7452	8.1426	35	0.6618	0.6849	0.7081	90	0.1127	0.1187	0.1249
-20	7.0027	7.3649	7.7388	36	0.6377	0.6602	0.6828	91	0.1096	0.1155	0.1215
-19	6.6631	7.0042	7.3561	37	0.6147	0.6365	0.6586	92	0.1066	0.1124	0.1183
-18	6.3419	6.6632	6.9945	38	0.5926	0.6139	0.6354	93	0.1037	0.1093	0.1151
-17	6.0380	6.3408	6.6527	39	0.5714	0.5921	0.6131	94	0.1009	0.1064	0.1121
-16	5.7504	6.0358	6.3296	40	0.5510	0.5713	0.5917	95	0.0982	0.1036	0.1091
-15	5.4781	5.7472	6.0240	41	0.5315	0.5512	0.5712	96	0.0956	0.1009	0.1063
-14	5.2196	5.4733	5.7341	42	0.5128	0.5320	0.5514	97	0.0931	0.0982	0.1035
-13	4.9748	5.2140	5.4599	43	0.4948	0.5136	0.5325	98	0.0906	0.0956	0.1008
-12	4.7428	4.9685	5.2003	44	0.4776	0.4958	0.5143	99	0.0882	0.0931	0.0982
-11	4.5230	4.7359	4.9545	45	0.4610	0.4788	0.4968	100	0.0859	0.0907	0.0957
-10	4.3146	4.5156	4.7217	46	0.4451	0.4625	0.4800	101	0.0837	0.0884	0.0933
-9	4.1165	4.3063	4.5007	47	0.4299	0.4468	0.4639	102	0.0815	0.0861	0.0909
-8	3.9287	4.1079	4.2913	48	0.4152	0.4317	0.4484	103	0.0794	0.0839	0.0886
-7	3.7505	3.9197	4.0928	49	0.4012	0.4172	0.4335	104	0.0774	0.0818	0.0864
-6	3.5815	3.7413	3.9047	50	0.3876	0.4033	0.4191	105	0.0754	0.0797	0.0842
-5	3.4209	3.5719	3.7262	51	0.3746	0.3899	0.4054	106	0.0735	0.0777	0.0821
-4	3.2683	3.4110	3.5567	52	0.3621	0.3770	0.3921	107	0.0716	0.0758	0.0801
-3	3.1233	3.2582	3.3958	53	0.3501	0.3646	0.3793	108	0.0698	0.0739	0.0781
-2	2.9856	3.1131	3.2431	54	0.3385	0.3527	0.3670	109	0.0681	0.0720	0.0762
-1	2.8547	2.9752	3.0981	55	0.3274	0.3412	0.3552	110	0.0663	0.0702	0.0743
0	2.7303	2.8443	2.9604	56	0.3167	0.3301	0.3438	111	0.0647	0.0685	0.0725
1	2.6118	2.7197	2.8294	57	0.3064	0.3195	0.3329	112	0.0631	0.0668	0.0707
2	2.4992	2.6012	2.7050	58	0.2965	0.3093	0.3223	113	0.0616	0.0652	0.0690
3	2.3921	2.4886	2.5868	59	0.2869	0.2994	0.3121	114	0.0601	0.0636	0.0674
4	2.2901	2.3815	2.4743	60	0.2777	0.2899	0.3023	115	0.0586	0.0621	0.0658
5	2.1931	2.2796	2.3674	61	0.2689	0.2807	0.2929	116	0.0572	0.0606	0.0642
6	2.1006	2.1825	2.2656	62	0.2604	0.2719	0.2838	117	0.0558	0.0592	0.0627
7	2.0126	2.0901	2.1688	63	0.2521	0.2634	0.2750	118	0.0545	0.0578	0.0612
8	1.9287	2.0022	2.0766	64	0.2442	0.2552	0.2665	119	0.0531	0.0564	0.0598
9	1.8488	1.9184	1.9889	65	0.2366	0.2473	0.2583	120	0.0519	0.0551	0.0584
10	1.7726	1.8386	1.9053	66	0.2293	0.2397	0.2505	121	0.0507	0.0538	0.0570
11	1.7000	1.7625	1.8257	67	0.2222	0.2324	0.2429	122	0.0495	0.0525	0.0557
12	1.6307	1.6900	1.7498	68	0.2154	0.2254	0.2356	123	0.0483	0.0513	0.0545
13	1.5646	1.6208	1.6776	69	0.2088	0.2185	0.2285	124	0.0472	0.0501	0.0532
14	1.5016	1.5549	1.6086	70	0.2024	0.2120	0.2217	125	0.0461	0.0490	0.0520
15	1.4415	1.4920	1.5430								