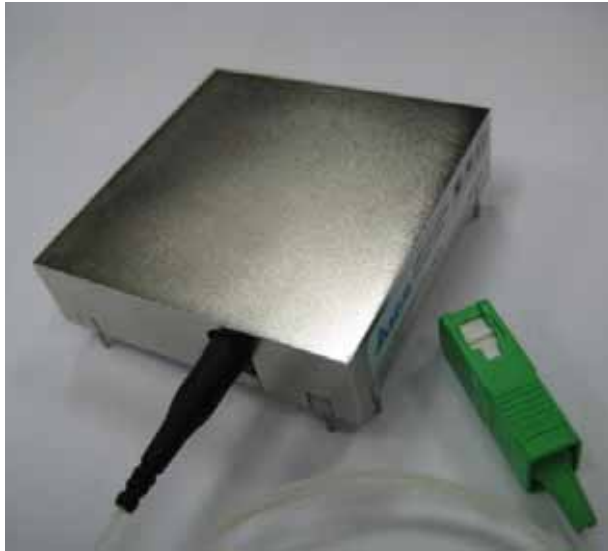


2.488Gbps Downstream/1.244Gbps Upstream Three-Wavelength GPON ONU Transceiver



FEATURES

- RoHS compliant
- SMF pigtail fiber with SC/APC connector
- Tx 1310nm/ Rx 1490nm (Digital)/ Rx 1555nm (Video)
- Supports asymmetrical 2488 Mbps downstream and 1244 Mbps upstream
- Video Disable/Enable control for power saving mode; RF and Optical output indications
- Support Industrial temperature operating
- Laser class 1 product which comply with the requirements of IEC 60825-1 and IEC 60825-2

Description

DELTA's Triplex burst mode ONU transceiver is designed to be compliant with the point to multipoint (P2MP) optical network transmission. It is compliant with ITU-T G.984.2 standard. The module consists of 1310nm un-cool DFB laser, InGaAs/InP APD, Preamplifier, analog PD and WDM filter in a highly-integrated three-wavelength optical sub-assembly, and it receives up to 2.5Gbps of continuous data at 1490nm, and transmits 1.25Gbps of burst-mode data at 1310nm. It also supports third wavelength to receive analog RF video at 1555nm.

The optical RF Video receiver consists of a wideband video amplifier that operates from 40MHz to 870MHz and supports up to 110 TV channels.

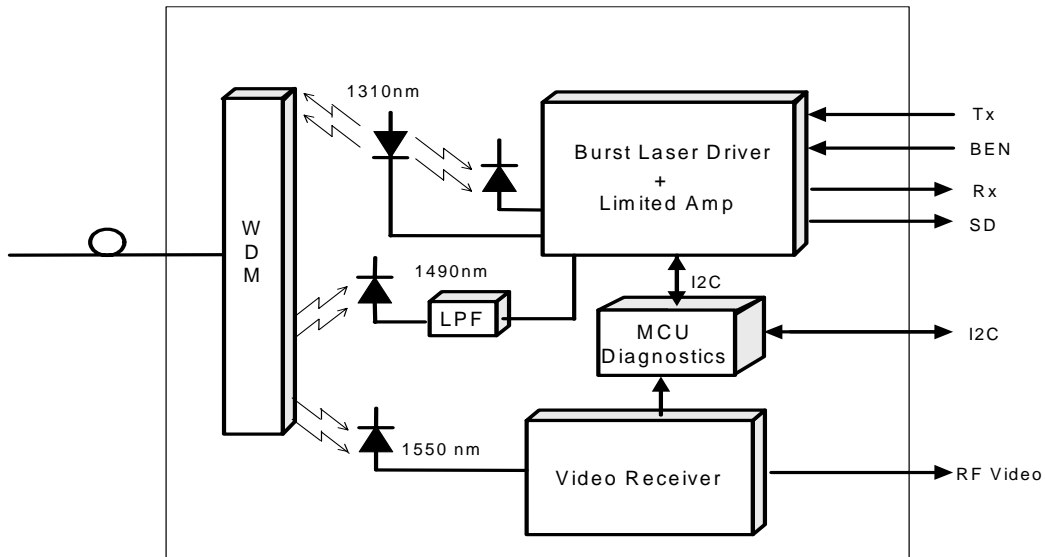
Application

- ITU-T G.984.2 compliant
- GPON ONU Class B+
- Burst mode application
- FTTx WDM Broadband Access

Performance

- OPGP-34-C4B3BDH data link up to 20km in 9/125um single mode fiber.

Block Diagram



1. Absolute Maximum Ratings

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Storage Temperature	T _s	-40		85	°C	
Storage Ambient Humidity	HA	5		95	%	
Power Supply Voltage (Digital 3.3V)	V _{CC}	0		5	V	
Power Supply Voltage (Analog 12V)		0		15	V	
Signal Input Voltage		-0.3		V _{CC} +0.3	V	
Optical Input Power (Peak)				+4	dBm	
Lead Soldering Temperature	T _{SOLD}			260	°C	
Lead Soldering Time	t _{SOLD}			10	sec	

2. Recommended Operating Conditions

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Operating Case Temperature	T _C	-10		85	°C	
Ambient Humidity	HA	5		85	%	Non-condensing
Power Supply Voltage (Digital 3.3V)	V _{CC}	3.13	3.3	3.47	V	
Power Supply Voltage (Analog 12V)		10.8	12	13.2	V	
Power Supply Current (Digital 3.3V)	I _{CC}			400	mA	
Power Supply Current (Analog 12V)				210	mA	
Power Supply Noise Rejection				100	mVp-p	100Hz to 1MHz
Data Rate of Transmitter			1244.16		Mbps	
Data Rate of Receiver			2488.32		Mbps	
Line Code		Scrambled NRZ				
Transmission Distance				20	km	

3. Transmitter Specifications

(T_C = 0 to +70 °C ,V_{cc} = 3.13 to 3.47V, Data Rate = 1244.16Mbps)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Average Launched Power	P _O	+0.5		+5	dBm	Note (1)
Optical Extinction Ratio	ER	10			dB	
Jitter Generation				0.33	Ulp-p	4KHz~10MHz
Output Eye Mask		Compliant with ITU-T G.984.2				Note (2)
Center Wavelength	c	1260		1360	nm	DFB Laser
Transmitter OFF Output Power	P _{Off}			-45	dBm	
-20dB Spectrum Width (RMS)				1	nm	
Side Mode Suppression Ratio	SMSR	30			dB	
Tx Enable Time	T _{on}			16	bits	Note (3)
Tx Disable Time	T _{off}			16	bits	
Tolerance to the Transmitter's incident Light Power		-15			dB	
Differential Data Input Swing (TX Data and Burst Enable)	V _{DT}	200		1800	mV _{p-p}	LVPECL Required external bias termination
Input common mode voltage (TX Data and Burst Enable)	V _{CM}	1.4		V _{cc} -0.2	V	

Note (1). Launched power (avg.) is end-of-life power coupled into a single mode fiber.

Note (2). Transmitter eye mask definition shown in Fig. 1.

Note (3). Ton/Toff time definition shown in Fig. 2

4. Transmitter Burst Mode Characteristics

V _{ccT} (TX_Dis*)	TX_Burst	Data Input	Optical Output
< 0.8V	X	X	OFF
> 2V	Low	X	OFF
	High	No	Other
		Yes	Laser bias and modulation signal output

X = Don't care

Other = Less than +8dBm (peak)

High = Logic high level, Low = logic low level

No = Data NOT Present, Yes = Data Present,

OFF = Optical Power is less than -45dBm

*V_{ccT}(Pin13) is internally connected to TX_Dis.

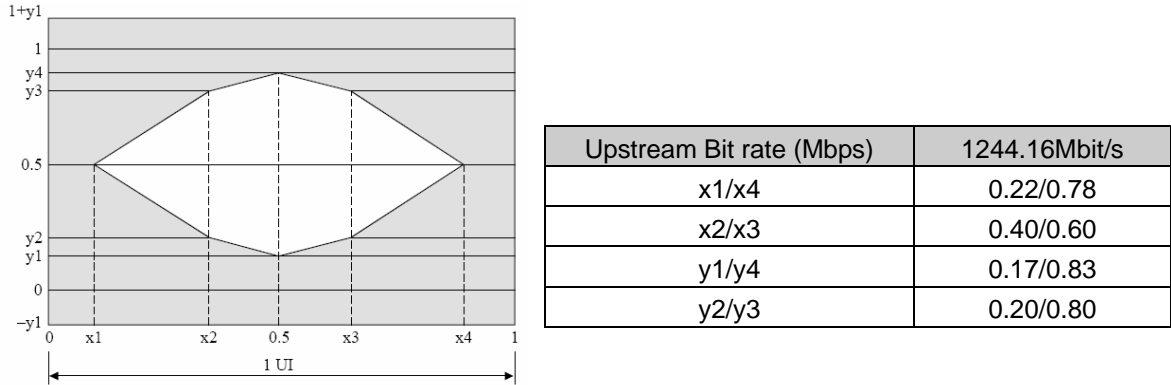
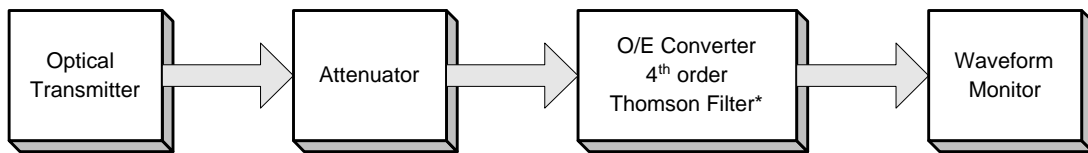


Fig. 1 (a) Optical Eye Mask

Eye Mask Test Setup



* $f_{-3dB} = 0.75$ times the nominal bit rate.

Fig. 1 (b) Eye Mask Test Setup

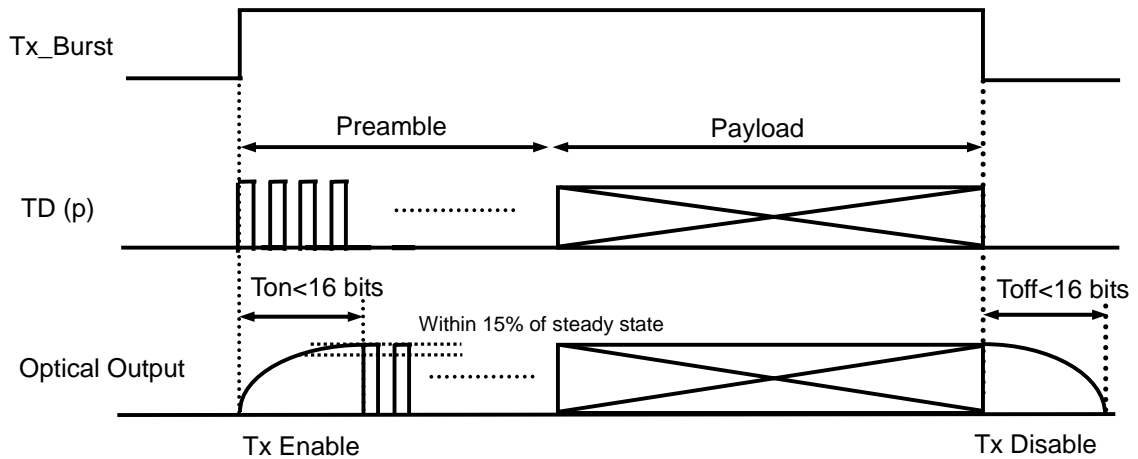


Fig. 2 Ton/Toff Time Definition

5. Receiver Specifications

($T_C = 0$ to $+70$ °C , $V_{CC} = 3.13$ to 3.47 V, Data Rate = 2488.32 Mbps)

Parameter	Symbol	Min.	Typ.	Max.	Unit	Note
Input Optical Wavelength	λ_{IN}	1480		1500	nm	APD
Receiver Sensitivity	P_{IN}			-28	dBm	Note (1)
Input Saturation Power (Overload)	P_{SAT}	-8			dBm	
Signal Detect- Assert Power	P_A			-28	dBm	
Signal Detect- Deassert Power	P_D	-44			dBm	Note (2)
Signal Detect- Hysteresis	$P_A - P_D$	0.5	2	6	dB	
Consecutive Identical Bit Immunity		72			bits	
Tolerance to reflected optical power				10	dB	
Optical Isolation of Receiver		40			dB	
Total Supply Current	I_{CC}			400	mA	Note (3)
Differential Data Output Swing	V_{DR}	400		1200	mV _{p-p}	AC-Coupled CML
Signal Detect Output Voltage-High	V_{LOSH}	2.4		V_{CC}	V	LVTTTL
Signal Detect Output Voltage-Low	V_{LOSL}	0		0.4	V	
Signal Detect- Assert/Deassert Time				100	us	

Note (1). Measured with 1490nm, ER=10dB; BER $\leq 10^{-10}$ @ PRBS=2²³-1 NRZ without FEC

Note (2). When Signal Detect Deasserted, the data output is at Low-level (fixed)

Note (3). Total Supply Current includes transmitter, receiver and MCU.

6. Optical Characteristics

Parameter	Condition	Min.	Typ.	Max.	Unit	Note
Optical Crosstalk at Digital Rx				-47	dB	
Optical Crosstalk at Analog Rx				-47	dB	
Optical Isolation at Digital Rx	1550~1560 nm	40			dB	
Optical Isolation at Digital Rx	1260~1360 nm	40			dB	
Optical Isolation at Analog Rx	1480~1500 nm	30			dB	
Optical Isolation at Analog Rx	1260 ~1360 nm	40			dB	
Optical Return Loss	1480~1500 nm			-20	dB	
Optical Return Loss	1550~1560 nm			-30	dB	

7. Specification of RF Video Receiver

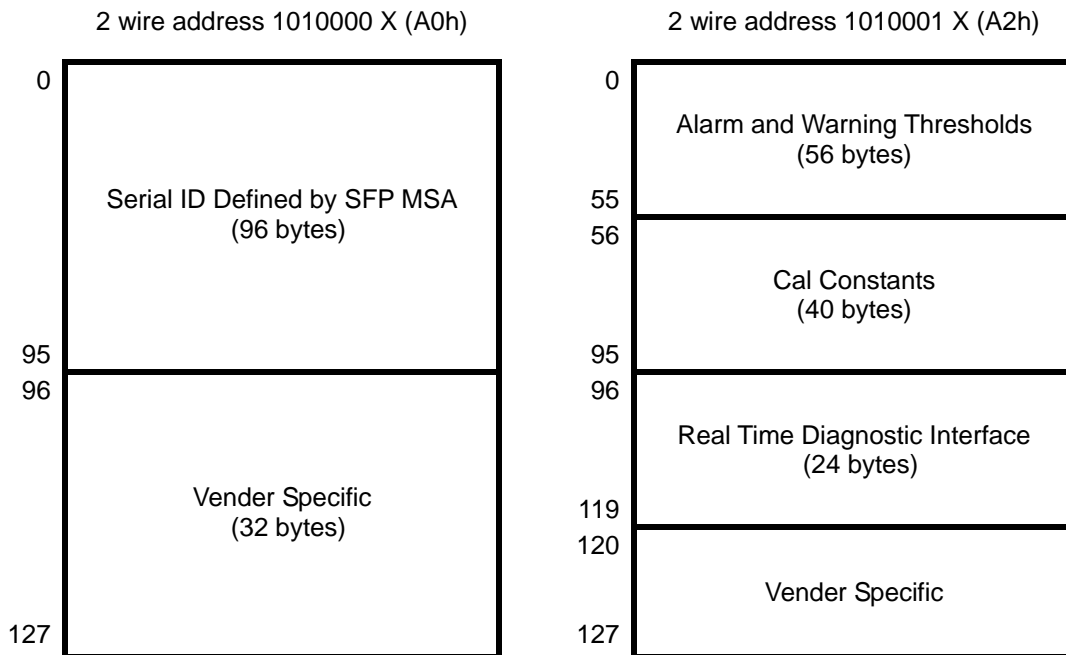
Parameter		Symbol	Min.	Typ.	Max.	Unit	Note
Operating Wavelength			1550		1560	nm	
Optical Input Range Level			-8		+2	dBm	1555nm
Optical Responsivity		R	0.9			A/W	
Equivalent Thermal Noise		EIN			8	pA/ Hz	Including Photodiode
RF Output Power			18			dBmV	
Total RF Output Power				36		dBmV	
Pass Band Bandwidth			40		870	MHz	
Gain Tilt			2		6	dB	
Gain Flatness					±0.5	dB/6MHz	
Output Impedance				75		ohm	
RF Output Return Loss		S_{22}			-12	dB	
Analog Video	Carrier to Noise Ratio	CNR	45			dB	Note (1)
	Composite Second Order	CSO		-58	-55	dBc	
	Composite Triple Beat	CTB		-63	-60	dBc	
Digital Video	Signal to Noise Ratio	SNR	39			dB	Note (2)

Note (1). Analog AM-VSB signal from 40 to 552 MHz with OMI of 3.5% per channel

Note (2). Digital 64/256 QAM modulated carrier from 552 to 870 MHz with OMI of 1.75% per channel

8. Enhanced Digital Diagnostic Interface

The memory map in the following describes an extension to the memory map defined in SFF-8472 MSA. The enhanced interface uses the two wire serial bus address 1010001X(A2h) to provide diagnostic information about the module's present operating conditions.



8.1 Digital Diagnostic Monitor Accuracy

Parameter	Accuracy	Unit	Calibration	Note
Transceiver Internal Temperature	± 3		Internal	TC=-40~+85
Digital Power Supply Internal Voltage	± 3%	V	Internal	VCC=3.3V±5%
TX Bias Current	± 10%	mA	Internal	Specified by nominal bias value
TX Optical Power				Not implement.
1490nm RX Optical Power	± 3dB	dBm	Internal	-28 to -8dBm
RF output power	± 3dB	dBmV	Internal	20~50dBmV
1555nm Rx Optical Power	± 3dB	dBm	Internal	-8 to +2dBm

Note. Temperature and Voltage is measured internal to the transceiver.

8.2 EEPROM Serial ID Memory Contents (2-Wire Address A0h)

Address	Name of Field	Hex	Description
Base ID Fields			
00	Identifier	02	SFF physical device (soldered device)
01	Ext. Identifier	04	Serial ID module supported
02	Connector	0B	Optical pigtail
03-10	Transceiver Codes	00	Undefined for GPON
11	Encoding	03	Compatible with NRZ encoding code
12	BR, Nominal	0C	Nominal 1244Mbps (indicate transmitter data rate)
13	Reserved	00	
14	Length (9um)-km	14	20km @9/125um fiber
15	Length (9um)-100m	C8	20000m @9/125um fiber
16-18	Length for MMF	00	Undefined for GPON
19	Reserved	00	
20-35	Vendor Name	44 45 4C 54 41 20	"DELTA" (ASCII character)
36	Channel Spacing	00	Undefined
37-39	Vendor OUI	00	Undefined
40-55	Vendor P/N	4F 50 47 50 2D 33 34 2D 43 34 42 33 42 44 20 20	"OPGP-34-C4B3BD" (ASCII character)
56-59	Vendor P/N Rev.	53 30 30 30	"S0" (ASCII character)
60-61	Laser Wavelength	05 1E	1310nm in Hex byte
62	DWDM Wavelength Fraction	00	Undefined
63	CC_BASE	XX	Check sum of bytes 0-62
Extended ID Fields			
64-65	Options	00 04	Signal Detect is implemented
66	BR, Max.	00	Undefined
67	BR, Min.	00	Undefined
68-83	Vendor SN	SN	Vendor serial number in ASCII character
84-91	Date Code	DC	Vendor date code in ASCII character
92	Diagnostic Monitoring Type	28	Implemented with internal calibration and received power measurement type by Avg. power
93	Enhanced options	F0	Alarm/Warning flags monitor are implemented
94	SFF-8472 compliant	02	SFF-8472 compliant with revision 9.5
95	CC_EXT	XX	Check sum of bytes 64-94
Vendor Specific ID Fields			
96-127	Vendor Specific	00	Vendor specific EEPROM

Digital Diagnostic Monitoring Interface (2-Wire Address A2h)

Address	# Bytes	Name of Field	HEX	Real Value	Unit
00-55	56	Alarm and Warning Threshold			
56	1	Reserved			
57	1	“Read/write bit”, RF_Offset		RF AGC control, 8-bit signed, LSB=0.1dB. The function is defined increase/ decrease total RF power. RF_OFFSET (Default=0).	
58	1	“Read Bit”, RFMON_Delta (MSB)		RFMON_Target(Default=37dBmV)-RFMON_Actual(RF power Monitor). Used to verify if AGC is working, 16-bit signed Int	
59	1	“Read Bit”, RFMON_Delta (LSB)			
60-92	33	Reserved			
93-94	2	Firmware version number			
95	1	Reserved			
96-109	14	Real Time Monitoring Data			
110-119	10	Status Bits and Alarm/Warning Flag Bits			

Alarm and Warning Thresholds (2 Wire Address A2h)

Address	# Bytes	Name of Field	HEX	Real Value	Unit
00-01	2	Temp High Alarm	69 00	105	
02-03	2	Temp Low Alarm	D8 00	-40	
04-05	2	Temp High Warning	64 00	100	
06-07	2	Temp Low Warning	E2 00	-30	
08-09	2	Voltage High Alarm	94 70	3.8	V
10-11	2	Voltage Low Alarm	6D 60	2.8	V
12-13	2	Voltage High Warning	87 8C	3.47	V
14-15	2	Voltage Low Warning	7A 44	3.13	V
16-17	2	Bias High Alarm	6B 6C	55	mA
18-19	2	Bias Low Alarm	00 00	0	mA
20-21	2	Bias High Warning	61 A8	50	mA
22-23	2	Bias Low Warning	05 DC	3	mA
24-25	2	TX Power High Alarm	FF FF	-	dBm
26-27	2	TX Power Low Alarm	FF FF	-	dBm
28-29	2	TX Power High Warning	FF FF	-	dBm
30-31	2	TX Power Low Warning	FF FF	-	dBm
32-33	2	1490 Power High Alarm	0C 5A	-5	dBm
34-35	2	1490 Power Low Alarm	00 08	-31	dBm
36-37	2	1490 Power High Warning	06 31	-8	dBm
38-39	2	1490 Power Low Warning	00 10	-28	dBm
40-41	2	1550 Power High Alarm	62 1F	+4	dBm
42-43	2	1550 Power Low Alarm	03 E8	-10	dBm
44-45	2	1550 Power High Warning	3D E9	+2	dBm
46-47	2	1550 Power Low Warning	06 31	-8	dBm
48-49	2	RF Power High Alarm	04 B0	60	dBmV
50-51	2	RF Power Low Alarm	01 2C	15	dBmV
52-53	2	RF Power High Warning	03 E8	50	dBmV
54-55	2	RF Power Low Warning	01 F4	25	dBmV

A/D Value (2 Wire Address A2h)

Address	# Bytes	Name of Field	Description
96-97	2	Temperature (MSB, LSB)	Internally measured module temperature
98-99	2	Supply Voltage (MSB, LSB)	Internally measured supply voltage in module
100-101	2	Tx Bias Current (MSB, LSB)	Internally measured TX Bias current
102-103	2	Tx Optical Power (MSB, LSB)	Not implemented.
104-105	2	1490 optical Power (MSB, LSB)	Monitored 1490nm optical power
106-107	2	1550 optical Power (MSB, LSB)	Monitored 1550nm optical power
108-109	2	RF Power (MSB, LSB)	Monitored RF output power

Notes:

Temperature (Signed twos complement value)

A2h Byte 96 (Temperature MSB)								A2h Byte 97 (Temperature LSB)							
S	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰	2 ⁻¹	2 ⁻²	2 ⁻³	2 ⁻⁴	2 ⁻⁵	2 ⁻⁶	2 ⁻⁷	2 ⁻⁸

Supply Voltage, Tx Bias Current, Tx Optical Power, Rx Received Power (Unsigned values)

A2h Byte 98 (V _{cc} MSB)								A2h Byte 99 (V _{cc} LSB)							
A2h Byte 100 (TX Bias MSB)								A2h Byte 101 (TX Bias LSB)							
A2h Byte 102 (TX Power MSB)								A2h Byte 103 (TX Power LSB)							
A2h Byte 104 (RX Power MSB)								A2h Byte 105 (RX Power LSB)							
2 ¹⁵	2 ¹⁴	2 ¹³	2 ¹²	2 ¹¹	2 ¹⁰	2 ⁹	2 ⁸	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰

The digital value conversions are updated every 13ms (nominal) or 20ms (max) in rotation. After getting digital value, each measurement could be obtained by multiplying digital value by corresponding LSB value:

$$\text{Temperature} = \text{Temp (Digital Value)} \times \text{LSB}_{\text{Temp}} = \text{Temp (Digital Value)} \times \frac{1}{256}; \text{ when Temperature} < 128$$

$$\text{Temperature} = \text{Temp (Digital Value)} \times \text{LSB}_{\text{Temp}} = [\text{Temp (Digital Value)} \times \frac{1}{256}] - 256; \text{ when Temperature} \geq 128$$

$$V_{cc} = V_{cc}(\text{Digital Value}) \times \text{LSB}_{V_{cc}} = V_{cc}(\text{Digital Value}) \times 100\mu\text{V}$$

$$\text{TX Bias Current} = \text{TX Bias Current (Digital Value)} \times \text{LSB}_{\text{TX,Bias}} = \text{TX Bias Current (Digital Value)} \times 2\mu\text{A}$$

$$\text{TX Power} = \text{TX Power (Digital Value)} \times \text{LSB}_{\text{TXPower}} = \text{TX Power (Digital Value)} \times 0.1\mu\text{W}$$

$$\text{RX Power} = \text{RX Power (Digital Value)} \times \text{LSB}_{\text{RXPower}} = \text{RX Power (Digital Value)} \times 0.1\mu\text{W}$$

$$1550 \text{ optical power} = 1550\text{RX Power (Digital Value)} \times \text{LSB}_{\text{RXPower}} = \text{RX Power (Digital Value)} \times 0.1\mu\text{W}$$

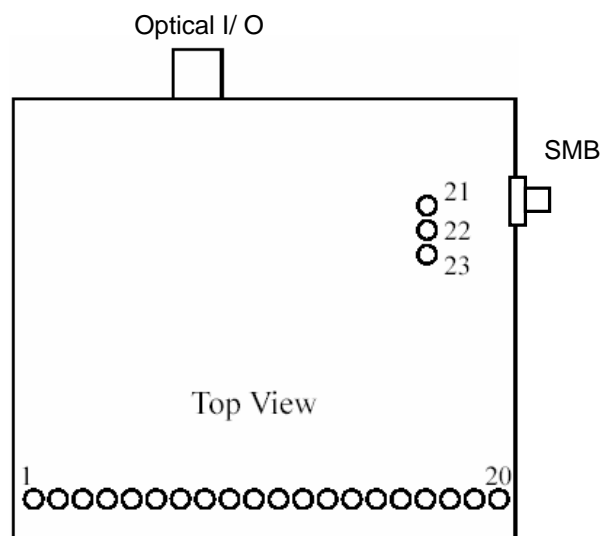
$$\text{RF Power} = \text{RF Power (Digital Value)} \times \text{LSB}_{\text{RFPower}} = \text{RX Power (Digital Value)} \times 0.05\text{dBmV}$$

Status Bits and Alarm/Warning Flag Bits (2 Wire Address A2h)

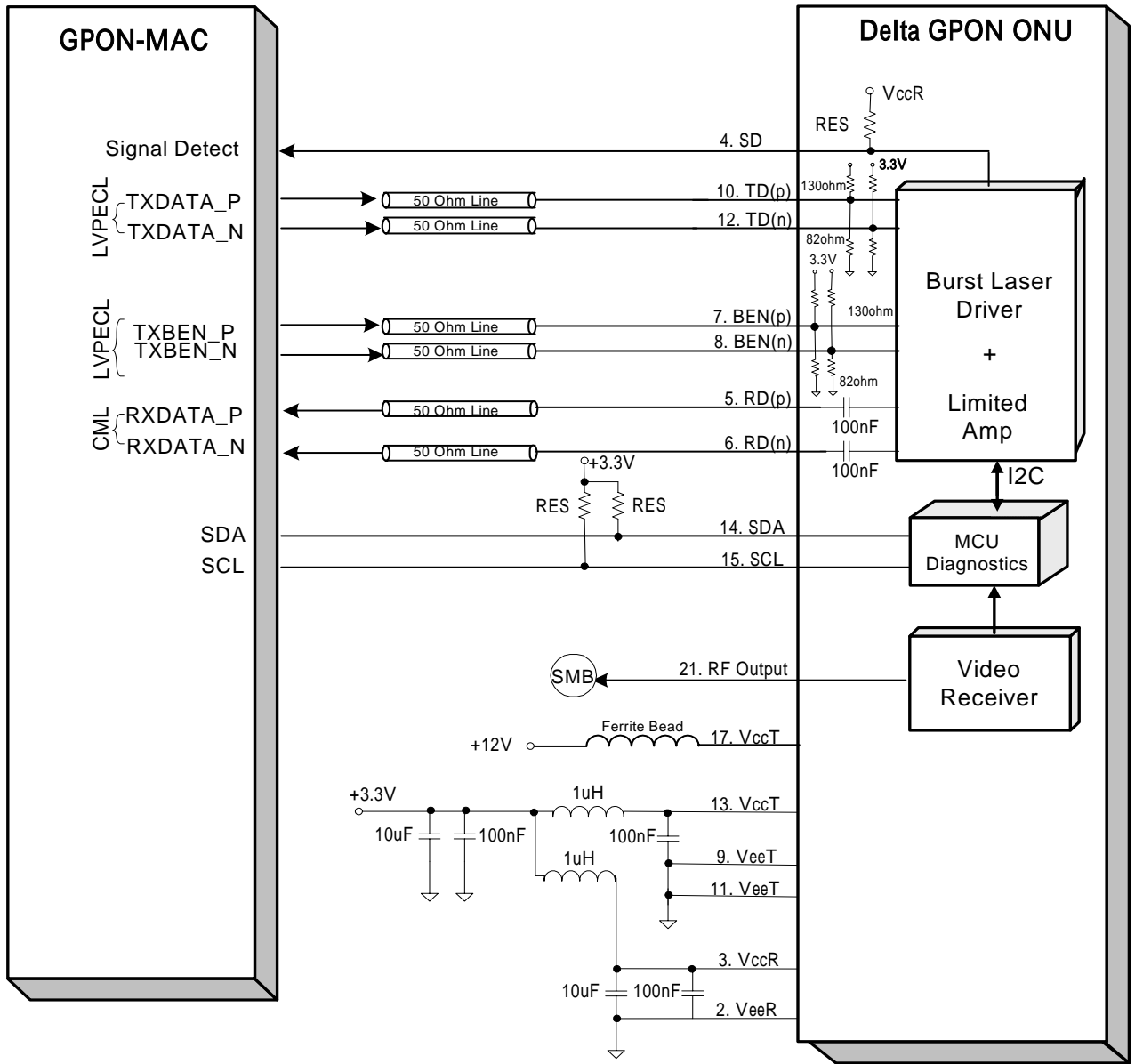
Address	Bit	Name	Description
110	7	Signal Detect State	Read bit. Digital state of SD output pin. 1=optical signal detected, 0=no optical signal detected
110	6	Interrupt	Read bit. Interrupt
110	5	TX Fault State	Read bit. 1=Tx failure state, 0=Tx normal state
110	4	Video Enable	Read/Write bit. RF Video Amplifier Enable, 1=Enable, 0=Disable
110	3	TX_Dis	Not Implemented
110	2	Reserved	
110	1	Reserved	
110	0	Reserved	
111	1-0	Soft Tx Mode	Read/write bit that allows software control of Tx power level 0, 1 and 2. Unsigned binary. (Not Implemented)
112	7	Temp High Alarm	Set when internal temperature exceeds high alarm level.
112	6	Temp Low Alarm	Set when internal temperature is below low alarm level.
112	5	Vcc High Alarm	Set when internal supply voltage exceeds high alarm level.
112	4	Vcc Low Alarm	Set when internal supply voltage is below low alarm level.
112	3	TX Bias High Alarm	Set when TX Bias current exceeds high alarm level.
112	2	TX Bias Low Alarm	Set when TX Bias current is below low alarm level.
112	1	<i>TX Power High Alarm</i>	<i>Not Implemented</i>
112	0	<i>TX Power Low Alarm</i>	<i>Not Implemented</i>
113	7	1490 Power High Alarm	Set when Received 1490 Power exceeds high alarm level.
113	6	1490 Power Low Alarm	Set when Received 1490 Power is below low alarm level.
113	5	1550 Power High Alarm	Set when Received 1550 Power exceeds high alarm level.
113	4	1550 Power Low Alarm	Set when Received 1550 Power is below low alarm level.
113	3	RF Power High Alarm	Set when RF output power exceeds high alarm level
113	2	RF Power Low Alarm	Set when RF output power below low alarm level
113	1-0	Reserved Alarm	
114	All	MASK0	Mask for byte 112
115	All	MASK1	Mask for byte 113
116	7	Temp High Warning	Set when internal temperature exceeds high warning level.
116	6	Temp Low Warning	Set when internal temperature is below low warning level.
116	5	Vcc High Warning	Set when internal supply voltage exceeds high warning level.
116	4	Vcc Low Warning	Set when internal supply voltage is below low warning level.
116	3	TX Bias High Warning	Set when TX Bias current exceeds high warning level.
116	2	TX Bias Low Warning	Set when TX Bias current is below low warning level.
116	1	<i>TX Power High Warning</i>	<i>Not Implemented</i>
116	0	<i>TX Power Low Warning</i>	<i>Not Implemented</i>
117	7	1490 Power High Warning	Set when Received 1490 Power exceeds high warning level.
117	6	1490 Power Low Warning	Set when Received 1490 Power is below low warning level.
117	5	1550 Power High Warning	Set when Received 1550 Power exceeds high warning level.
117	4	1550 Power Low Warning	Set when Received 1550 Power is below low warning level.
117	3	RF Power High Warning	Set when RF output power exceeds high warning level
117	2	RF Power Low Warning	Set when RF output power below low warning level
117	1-0	Reserved Warning	
118	All	MASK0	Mask for byte 116
119	All	MASK1	Mask for byte 117

9. Pin Description

Pin No.	I/O	Pin Name	Description
1		GND_A	Common Ground
2		VeeR	Digital receiver ground
3		VccR	Digital receiver power supply +3.3V
4	O	SD	Digital receiver signal detect (LVTTTL); Normal Optical Input indicated by logic "High", and No Optical Input indicated by logic "Low".
5	O	RD(p)	Non-Inverted Digital Receiver Data Output
6	O	RD(n)	Inverted Digital Receiver Data Output
7	I	BEN(p)	Non-Inverted Burst Enable Input
8	I	BEN(n)	Inverted Burst Enable Input
9		VeeT	Digital Transmitter Ground
10	I	TD(p)	Non-Inverted Transmitter Data Input
11		VeeT	Digital Transmitter Ground
12	I	TD(n)	Inverted Transmitter Data Input
13		VccT (TX_Dis)	Digital Transmitter Power Supply +3.3V
14	I/O	SDA	I2C Data Input/Output
15	I	SCL	I2C Clock Input
16	O	INT/NC	Interrupt: Module Fail Detect (LVTTTL), Low at Normal Operation / No Connect
17		Vdd_+12V	RF Video Power Supply +12V
18		MISO/NC	SPI Bus Master Input / No Connect
19	I	Reset/NC	u-Processor reset, Active Low (LVTTTL) / No Connect
20		GND_A	Analog Ground
21*		NA	NA
22*	O	NA	NA
23*		NA	NA
SMB**		RF Output	Video Output 75 Ohm



10. Recommended Interface Circuit



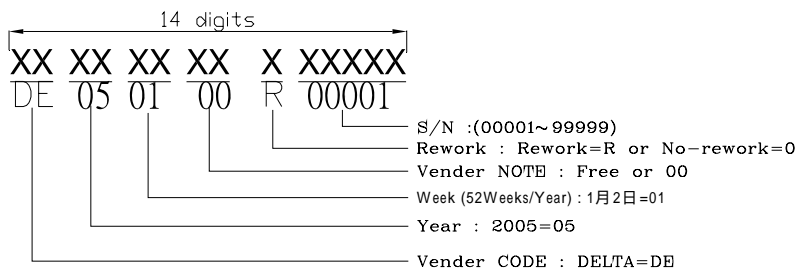
* RES is the internal 4.7K to 10K Ohms pull-up resistor.

11. Outline Dimensions

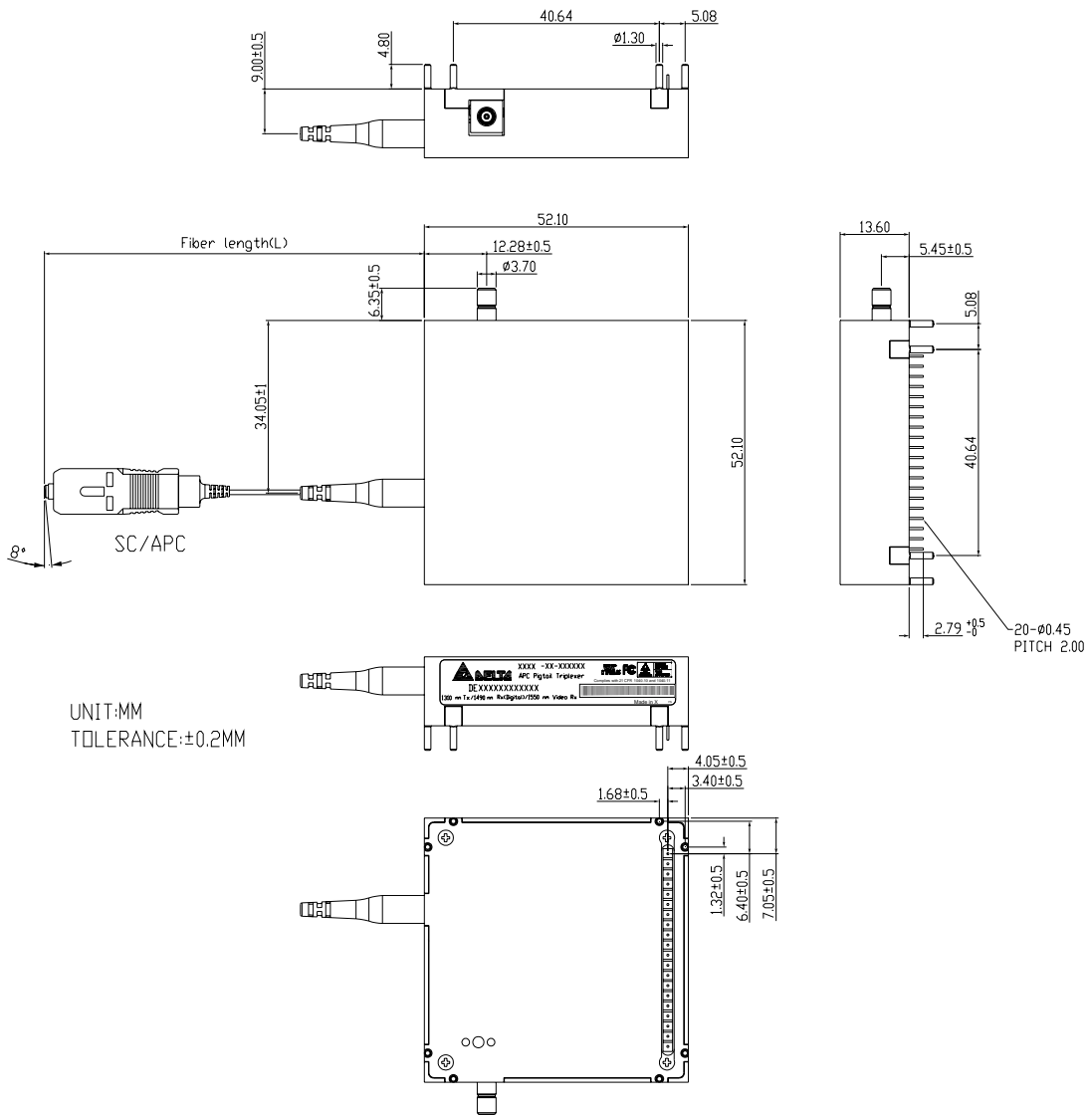
Parameter	Unit	Description	Note
Mechanical Dimensions	mm	52.1x52.1x13.6	
Connector Type	-	SC/APC connector	
Minimum Fiber Bending Radius	mm	20	
Maximum Fiber Contact Temperature	°C	85	
Tensile Force on Pigtail	Kg	1	
Maximum Fiber Stress Allowance	kpsi	200	
Fiber length (L)	mm	900+/-50	

11.1 Serial Number Coding

S/N



11.2 Outline Dimensions:



12. Regulatory Compliance

Feature	Test Method	Reference	Performance
Electrostatic Discharge (ESD) to the Electrical Pins	Human Body Model (HBM)	MIL-STD-883E Method 3015.7 EIA-JESD22-A114	(1) Satisfied with electrical characteristics of product spec. (2) No physical damage
	Machine Model (MM)	EIA-JESD22-A115	
Electrostatic Discharge (ESD) to the Simplex Receptacle	Contact Discharge	IEC/EN 61000-4-2	
	Air Discharge	IEC/EN 61000-4-2	
Radio Frequency Electromagnetic Field Immunity		IEC/EN 61000-4-3	
Electromagnetic Interference (EMI)		FCC Part 15 Class B EN 55022 Class B (CISPR 22A)	
Laser Eye Safety	FDA/CDRH	FDA 21CFR 1040.10, 1040.11	CDRH File # 0420993
	TUV	IEC/EN 60825-1 IEC/EN 60825-2	TUV Certificate # R50032471
Component Recognition	TUV	IEC/EN 60950	
	UL/CSA	UL 60950	UL File # E239394

Appendix A. Document Revision

Version No.	Date	Description
S0	2008-12-05	First Release
S1	2009-05-22	1. P2. Modify Ambient Humidity Max. to 85% 2. P9. Added the description on A2H Address 57-59. 3. P11. Added the 1550 optical power and RF Power monitor information. 4. P12. Added the A2H Byte 110 function description. 5. P14. Modify the Recommended interface circuit.