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Reviewed by	Approved by	Date	Rev	Reference
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LET (Liquid-crystal Electrical Tunable)

Contents

Features and specifications of the LET OTRx are presented.

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Preliminary

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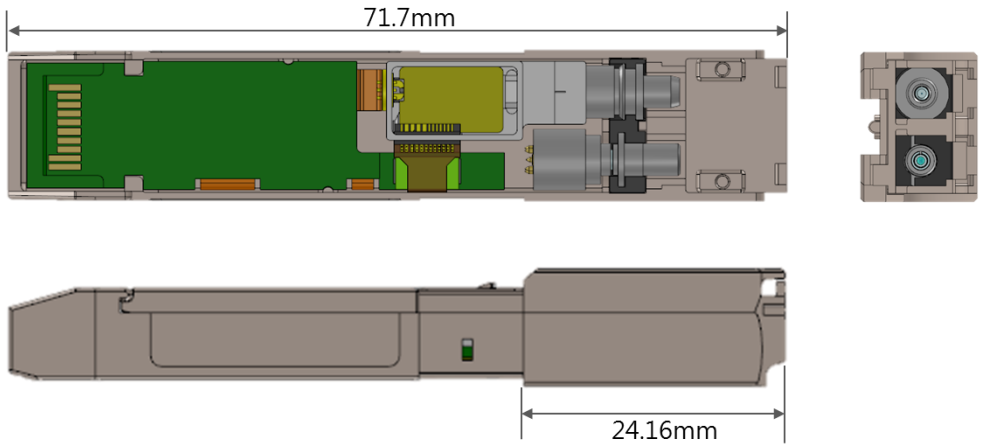
25 Gbps SFP28 Liquid-crystal Electrical Tuneable Transceiver

The liquid crystal electrical tuneable (“LET”) transceiver includes liquid crystal tunable filter as a key component enabling the optical transmitter to be tunable over a wide wavelength range. The output wavelengths are centred on the 150GHz spaced ITU grid within the specified tuning range in this document**.** The wide-range wavelength locker included in the transmitter provides capability of stabilizing wavelengths within +/- 25 pm EOL.



Main features

- Colorless (Plug & Play) Operation
  - LC/UPC receptacle
- Transmission
  - Data rates up to 25.78 Gbps (1 Gbps ~ 25.78 Gbps)
  - Transmission distance up to 20km in SSMF
- Operating temperature between -40 ^{o}C (ambient) and 85 ^{o}C (case)
  - Maximum power consumption of 3 W
- DWDM wavelength tunable transmitter
  - Operation in 1290nm CWDM band
  - Wavelength stability of +/- 20 pm BOL and +/- 25 pm EOL
- AMCC
  - Controls of such as wavelength setting, loopback, and others on remote TRx
  - Reading of real time DDM of remote TRx
  - Reading of designated registers of remote TRx
- Single 3.3V Supply
- Fully support digital diagnosis management interface and MSA standard
  - INF8074i, SFF-8083, SFF-8431, SFF-8432, SFF-8472, SFF-8690
- Class 1 Laser Eye Safety
- ROHS compliant
- Metal enclosure for lower EMI

Applications

- DWDM optical links

Wavelength Assignments

Table 1. 150GHz wavelength grid at 1290nm CWDM band

1290 nm CWDM			
150 GHz (0.8 nm) spacing			
CH	THz	nm	remark
0	230.750	1299.209	system use
1	230.900	1298.365	
2	231.050	1297.522	
3	231.200	1296.680	User use
4	231.350	1295.839	
5	231.500	1295.000	
6	231.650	1294.161	
7	231.800	1293.324	
8	231.950	1292.487	
9	232.100	1291.652	
10	232.250	1290.818	
11	232.400	1289.985	
12	232.550	1289.153	
13	232.700	1288.322	
14	232.850	1287.492	
15	233.000	1286.663	
16	233.150	1285.835	
17	233.300	1285.008	
18	233.450	1284.183	
19	233.600	1283.358	
20	233.750	1282.535	system use
21	233.900	1281.712	

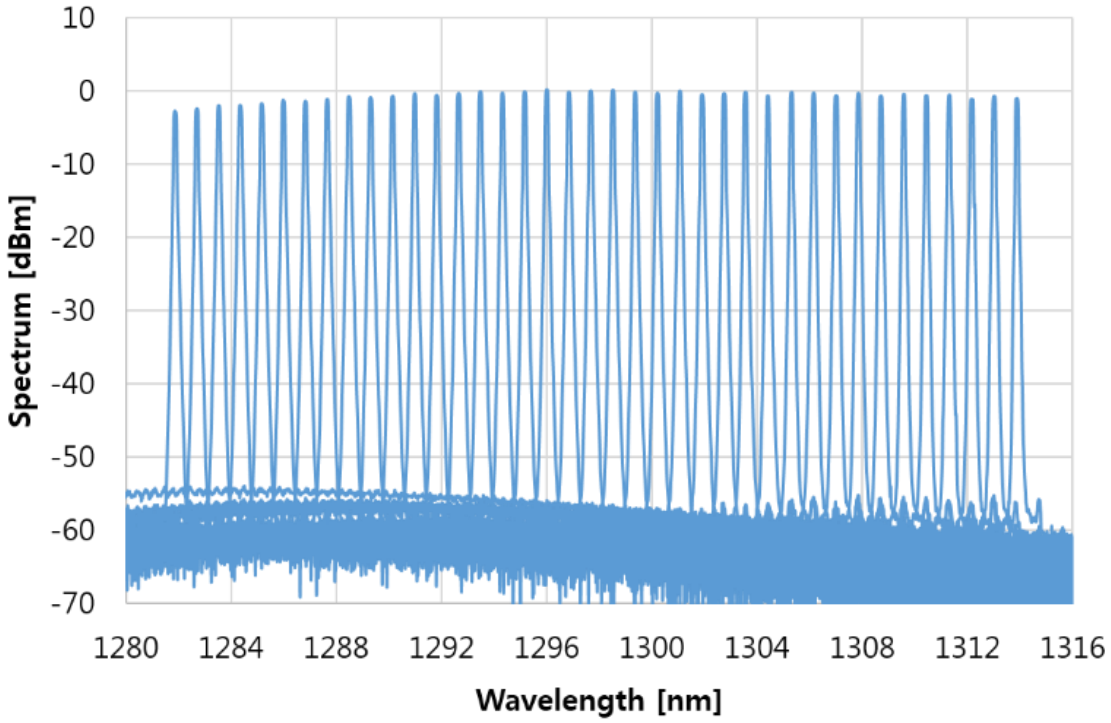
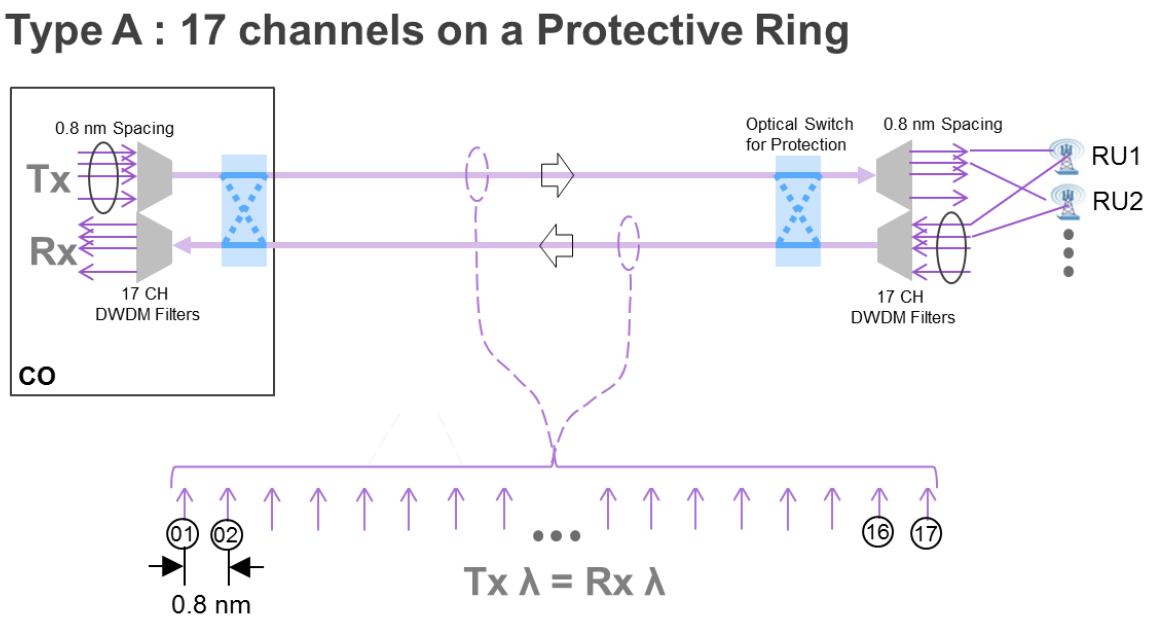


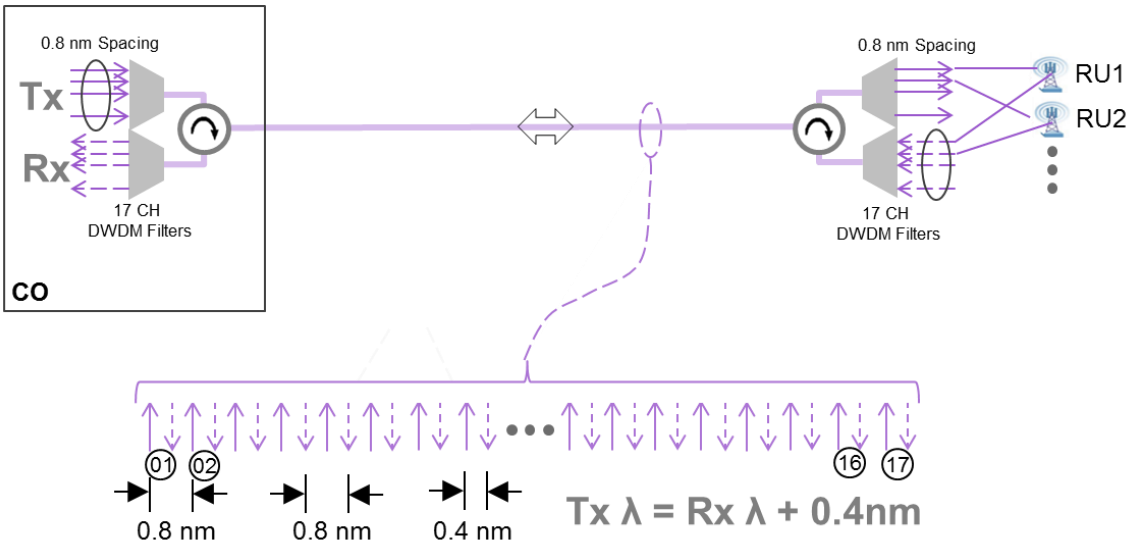
Figure 1. Tunable spectra around 1290nm CWDM band under 25.78Gbps modulation.

Optical link Configurations

Type-A (Protective Ring)



Type-B (Bidirectional Link)



Optical Filter Specifications

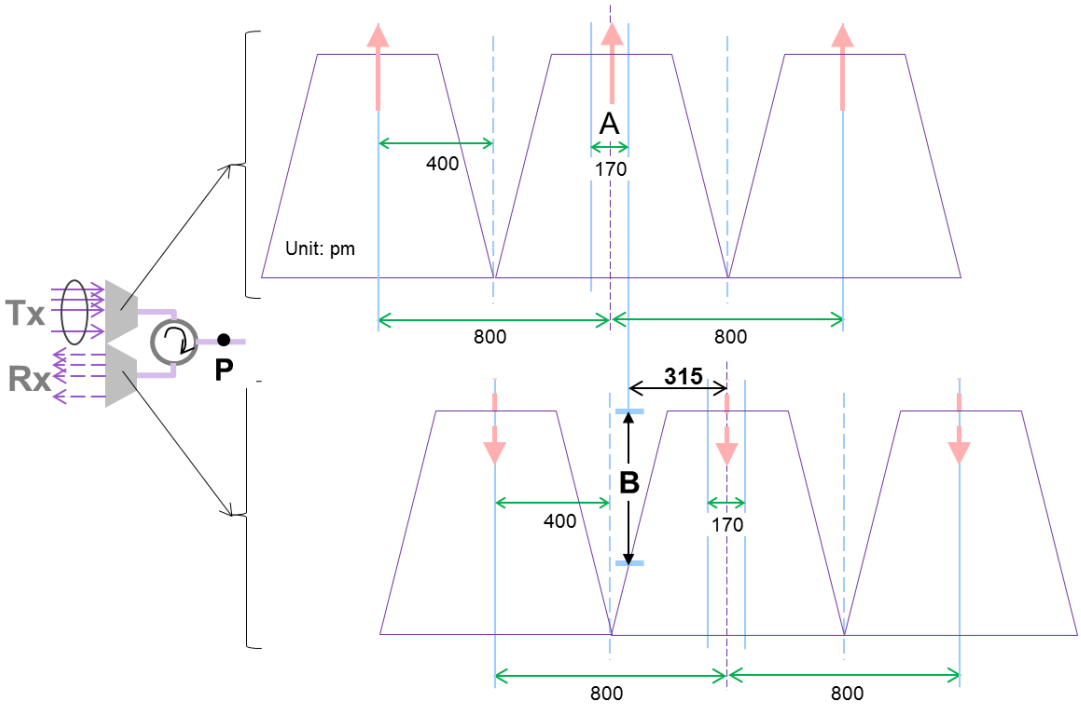


Table 2. Optical filter specifications.

Passband @ 0.5 dB (“**A**”)	> 170 pm
Isolation @ 315 pm off center (“**B**”)	> 18 dB
Channel Distance	800 pm
Max. Tx Reflection @ **P**	~ -13 dBm
Min. Rx Signal @ **P**	~ -17 dBm
Tx–Rx Isolation	> 8 dB (for 1E-12 BER)
Center Wavelength Accuracy of 0.5dB passband	< +/-40 pm
Insertion Loss	5 dB
Return Loss	45 dB
Operating Temperature	-40 – 85 ^{o}C
Storage Temperature	-40 – 85 ^{o}C
Connector Type	COM (SC/APC), CH (LC/UPC)

Absolute maximum ratings

When operating at conditions above these values, unexpected damages or failures may occur to the devices and negatively impact the reliability of the products.

Table 3. Absolute maximum ratings.

Items	Min	Typ	Max	Notes
Power supply voltage			4V	
Storage ambient temperature	-40 °C		85 °C	
Storage relative humidity	5% RH		95 % RH	w/o dew
Max Rx input power			-3 dBm	

Operating conditions

Table 4. Recommended operating conditions.

Items	Min	Typ	Max	Notes
Temperature	-40 °C		85 °C	1
Relative humidity	5% RH		90% RH	
Power supply current		0.5 A	0.9 A	@3.3V
Power Consumption			3.0 W	
Power supply voltage	3.135 V		3.465 V	

Note 1: Low bound at ambient, high bound at case

Transmitter specifications

Table 5. Transmitter specifications.

Items		Min	Typ	Max	Notes
Optical Transmit Power		-1 dBm	0 dBm	1 dBm	
Transmitter Disable Power(High Active)				-35 dBm	
Peak Wavelength		Refer to Table 1			
Tuning Range		1290nm CWDM band (refer to Table 1 & Figure 1)			
DWDM Channel spacing			150 GHz		
Wavelength Offset from ITU grid		-95 pm		+95 pm	
Wavelength Drift	BOL	-20 pm		20 pm	
	EOL	-25 pm		25 pm	
Extinction Ratio		5 dB			@25.78Gbps
Side Mode Suppression Ratio		45 dB			
RMS Spectral Width				0.45 nm	
Transmitter Optical Mask Margin		5 %			1
TOPM Accuracy		-3 dB		+3 dB	
Data Rate		1 Gbps		25.78 Gbps	
Data input differential swing		190 mV		1000 mV	
Input differential impedance			100 ohm		
Tx disable (high)		2.0 V		Vcc+0.3 V	
Tx disable (low)		-0.3 V		0.8 V	
Tx disable Assert Time				100 us	
Tx disable DeAssert Time				2 ms	
Tx Fault (high)		2.4 V		Vcc+0.3 V	
Tx Fault (low)		-0.3 V		0.4 V	
Tx Fault Assert Time				1 ms	

Note 1: 25.78 Gpbs, PRBS31, after 20km fiber. Target hit ratio~5E-5 with IEEE 802.3 compatible mask.

Receiver specifications

Table 6. Receiver specifications.

Items	Min	Typ	Max	Notes
Operating wavelength	1260 nm		1620 nm	
Rx sensitivity			-20 dBm	1
Rx overload	- 4 dBm			
LOS assert	-40 dBm			
LOS de-assert			-22 dBm	
LOS Hysteresis	1.25 dB	2.1 dB		
Receiver Reflectance			-27 dB	
RSSI accuracy	-3 dB		+3 dB	
Data Rate	1.0 Gbps		25.78 Gbps	
Data output differential swing	450 mV		1050 mV	2
Differential output impedance		100 ohm		
Rx LOS (high)	2.4 V		Vcc+0.3 V	
Rx LOS (low)	-0.3 V		0.4 V	
Rx LOS Assert Time			80 us	
Rx LOS DeAssert Time			80 us	

Note 1: 25.78 Gbps (PRBS31), 20km, BER=$5x10^{-5}$, AMCC.
Note 2: Internally AC-coupled.

Electric pin description

Table 7. Electric pin description.

Pin	Symbol	Description	Note	Pin	Symbol	Description	Note
1	Tx GND(VeeT)	Transmitter ground		11	RxGND(VeeR)	Receiver ground	
2	TxFault	Transmitter fault indication	1	12	RD-	Rx data out(-)	4
3	Tx Disable	Transmitter disable	2	13	RD+	Rx data out(+)	
4	MOD-DEF(2) (SDA)	Module Definition 2 (I2C)	3	14	RxGND(VeeR)	Receiver ground	
5	MOD-DEF(1) (SCL)	Module Definition 1 (I2C)		15	VccR	Rx power supply	
6	MOD_DEF(0) (GND)	Module Definition 0 (GND in module)		16	VccT	Tx power supply	
7	Rate Select	No connection		17	TxGND(VeeT)	Transmitter ground	
8	LOS	Los of signal	1	18	TD+	Tx data in(+)	5
9	RxGND(VeeR)	Receiver ground		19	TD-	Tx data in(-)	
10	RxGND(VeeR)	Receiver ground		20	TxGND(VeeT)	Transmitter ground	

Note 1: Open-collector outputs. It should be pulled up with 4.7kΩ~10kΩ resistor on the host board.
Note 2: Tx_Disable is internally pulled-up with 4.7kΩ resistor to VccTx.
VccTx ~ 0.8V : Tx on
0.8V ~ 2.0V : Undefined
2.0V ~ 3.465V : Tx disabled
N.C. : Tx disabled
Note 3: These 3 pins are the module definition pins.
MOD-DEF0 is grounded in module.
MOD-DEF1 is the clock line of two-wire serial interface for serial ID (up to 400Khz)
MOD-DEF2 is the data lines of two-wire serial interface for serial ID.
Note 4: Internally AC-coupled
Note 5: Internally AC-coupled

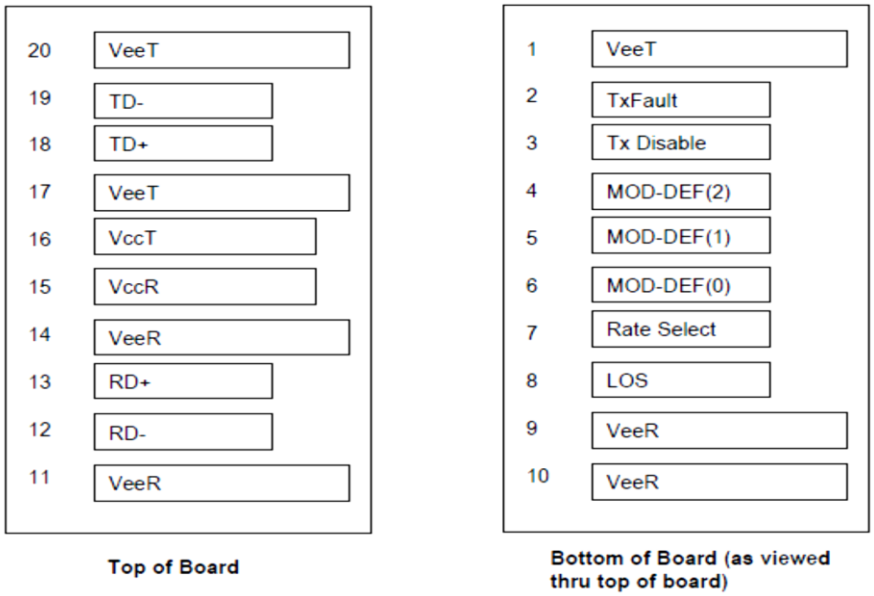


Fig. 2 SFP+ 20Pin connector.

Recommended interface circuit

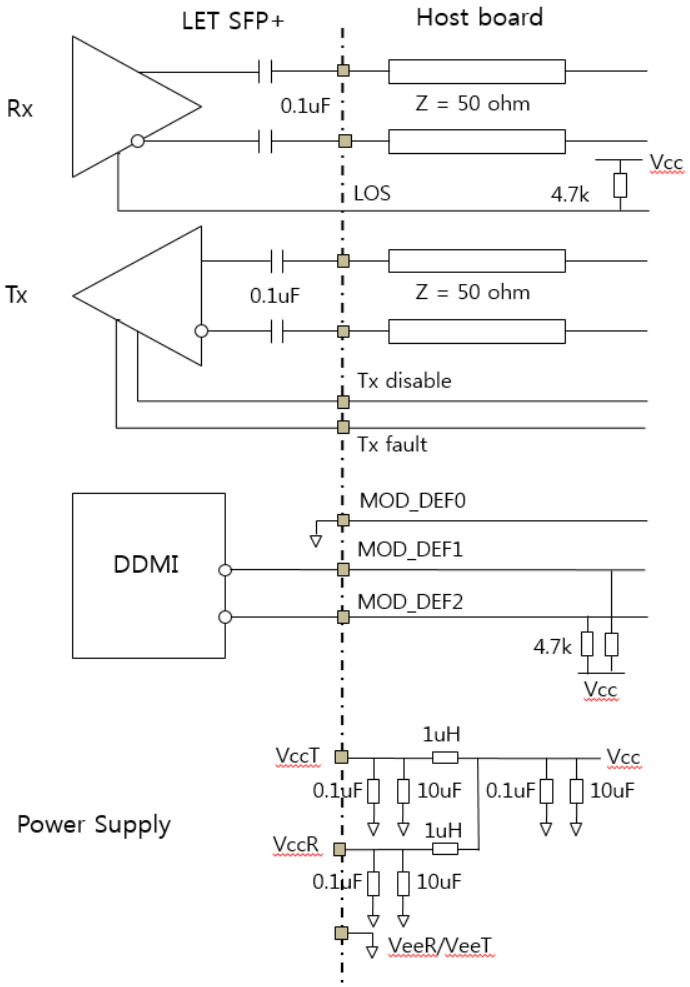


Fig. 3 Recommended interface circuit.

Mechanical dimension

The form factor complies with a standard SFP28 package. Refer to the SFF-8432. The pluggable fiber connector types are LC/UPC for Tx/Rx respectively.

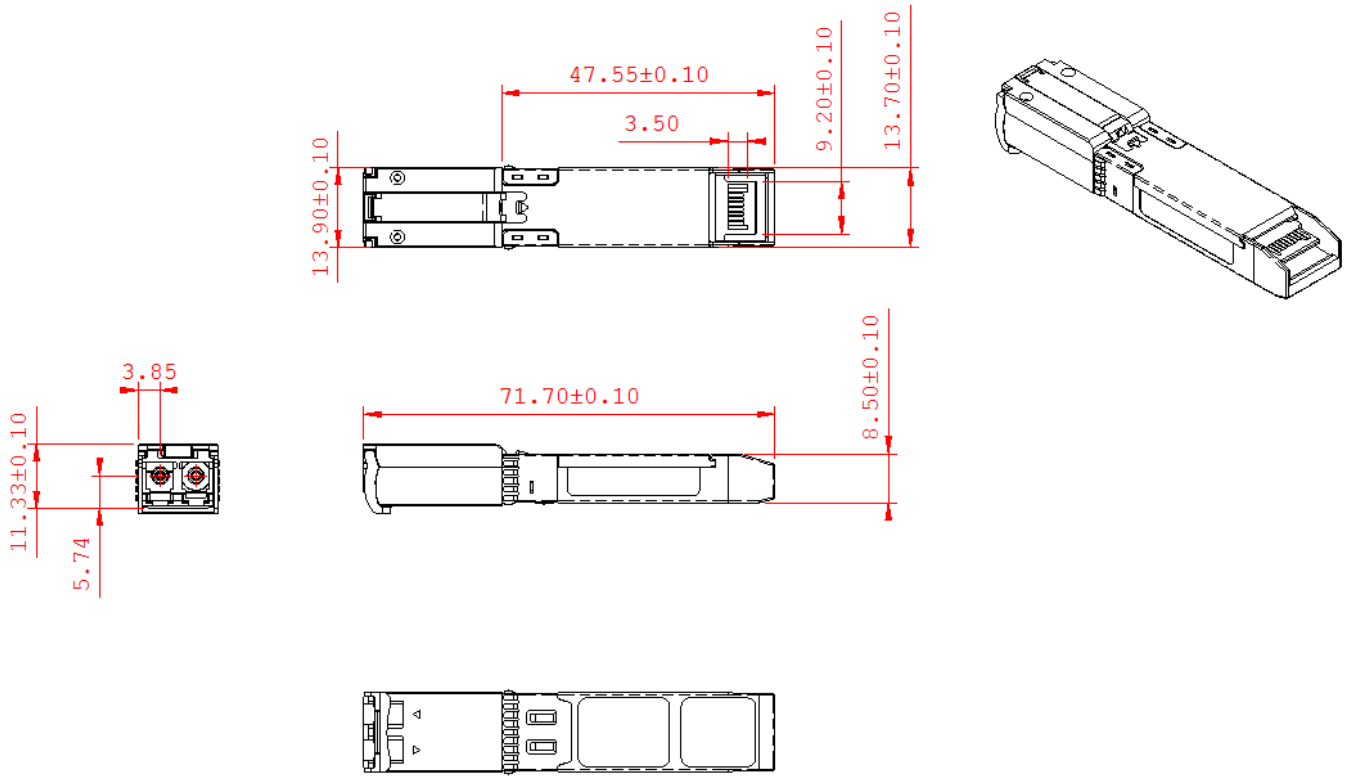
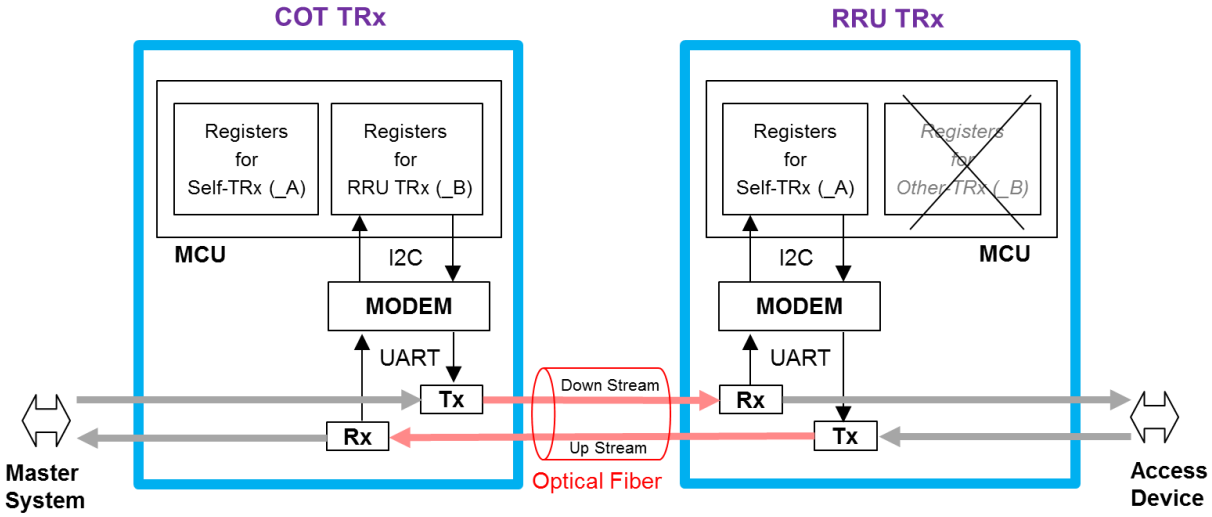


Fig. 3 Drawing of SFP+ housing.

Digital Diagnostics Function & Tuning Management Interface

As defined by the SFF-8472 , LET tunable SFP+ provide digital diagnostic functions via 2-wire serial interface, which allows real-time access to the following operating parameters. Note that register names with "_A" contain information for COT transceiver, while with "_B" for RU transceiver. Register names without these post fix are common for both transceivers. Note that as shown figures below, COT transceiver has both information for self ("_A") and for RU ("_B") – this remote information is updated on real time basis by AMCC, while RU transceiver has information only for self ("_A") and in this case information in "_B" registers has **not** any meaning.

AMCC operational structure



Memory mapping by AMCC

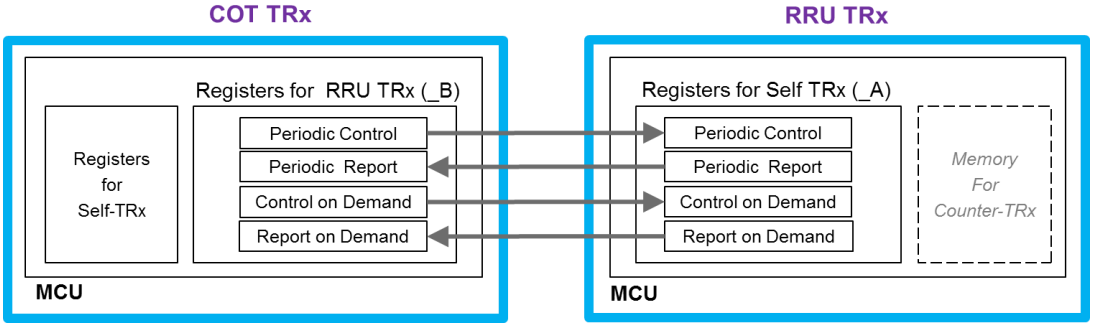


Table 8. Memory map.

Dev Addr	Tab Num	Reg Addr	Reg. Name	R/W	Bit	Description
0xA0		0x00	Identifier	RO		Type of serial transceiver
0xA0		0x01	Ext. Identifier	RO		Extended identifier for type of serial transceiver
0xA0		0x02	Connector	RO		Code for connector type - SC connector
0xA0		0x03	Reserved	RO		Infiniband standard not implemented
0xA0		0x04	Transceiver	RO	b0	SONET standard not implemented
					b1	SONET standard not implemented
					b2	1000BASE-Gigabit Ethernet not specified
					b3	Fiber Channel link length
					b4	Fiber Channel transmitter technology
					b5	Fiber Channel transmission media
					b6	Fiber Channel Speed - 8/4/2 GBd
0xA0		0x0B	Encoding	RO		Encoding mechanism
0xA0		0x0C	BR, Nominal	RO		Nominal Bit Rate
0xA0		0x0D	Reserved	RO		0
0xA0		0x0E	Length (9 um) - km	RO		20 km
0xA0		0x0F	Length (9 um) - m	RO		200 00m
0xA0		0x10	Length -OM2	RO		
0xA0		0x11	Length - OM1	RO		
0xA0		0x12	Length (copper)	RO		
0xA0		0x13	Length - OM3	RO		
0xA0		0x14	Vendor name	RO	b0	M
					b1	E
					b2	L
					b3	-
					b4	T
					b5	e
					b6	l
					b7	e
					b8	c
					b9	o
					b10	m
					b11	
					b12	
					b13	
					b14	
					b15	
0xA0		0x24	Transceiver	RO		
0xA0		0x25	Vendor OUI	RO	b0	
					b1	
					b2	

0xA0		0x28	Vendor PN (16 character ASCII)	RO	b0	X
					b1	X
					b2	X
					b3	X
					b4	X
					b5	X
					b6	X
					b7	X
					b8	X
					b9	X
					b10	X
					b11	X
					b12	X
					b13	X
					b14	X
					b15	X
0xA0		0x38	Vendor Rev	RO	b0	X
					b1	X
					b2	X
					b3	X
0xA0		0x3C		RO		
0xA0		0x3D		RO		
0xA0		0x3E	Reserved	RO		Reserved
0xA0		0x3F	CC_BASE	RO		Check code = (SUM of Bytes 0 to 62) MOD 256
0xA0		0x40	Transceiver options	RO		
0xA0		0x41	Transceiver options	RO		Tunable, TX_Disable, TX_Fault, LOS
0xA0		0x42	BR Max	RO		
0xA0		0x43	BR Min	RO		
0xA0		0x44	Vendor SN (16 character ASCII)	RO	b0	X
					b1	X
					b2	X
					b3	X
					b4	X
					b5	X
					b6	X
					b7	X
					b8	X
					b9	X
					b10	X
					b11	X
					b12	X
					b13	X
					b14	X
					b15	X
0xA0		0x54	Date code	RO	b0	X
					b1	X
					b2	X
					b3	X
					b4	X
					b5	X
0xA0		0x5A	Lot Code	RO	b0	Blank
					b1	Blank
0xA0		0x5C	Diagnostic Monitoring Type	RO		DD implemented, Internally Calibrated Received power measurement type = AOP
0xA0		0x5D	Enhanced Options	RO		Soft Status I/O
0xA0		0x5E	SFF-8472 compliance	RO		Rev 11.0
0xA0		0x5F	CC_EXT	RO		Check code = (SUM of Bytes 64 to 94) MOD 256
0xA0		0x60	Repeater Inventory	RO	16B	
0xA0		0x70	SELF Line Number	RO	32B	
0xA0		0x90	COUNTER RU Line Number	RO	32B	

Dev Addr	Table Num	Reg Addr	Reg Name	R/W	Bit	Description
0xA0		**0xB0**	CHN_A_user	WO	u08	User's input of channel number (refer to "Wavelength Assignment") CHN_B_user (channel for RU) is automatically determined by: **CHN_B_user = CHN_A_user** When directly type the channel number into RU T-SFP via I2C, type the passwd (38d) first at 0xA2-table 2- 0x83 address.
0xA0		0xB1	TRx_Control_A	WO	b0	Set (1) or Clear (0) Tx_Disable (default = 0)
					b1	Reserved (do NOT change for normal operation)
					b2	Reserved (do NOT change for normal operation)
					b3	Reserved (do NOT change for normal operation)
					b4	Reserved (do NOT change for normal operation)
					b5	Reserved (do NOT change for normal operation)
					b6	Reserved (do NOT change for normal operation)
					b7	Reserved (do NOT change for normal operation)
0xA0		0xB7	TRx_State0_A	RO	b0	Reserved
					b1	Wavelength Locking (0: unlocked, 1: locked)
					b2	Startup Ready (0: not ready, 1: ready)
					b3	Link Ready (0: not ready, 1: ready)
					b4	Tx Disable (0: not in TxDisable, 1: in TxDisable)
					b5	Rx LOS (0: not in LOS, 1: in LOS)
					b6	Loopback (0: not in Loopback, 1: in Loopback)
					b7	Rx Mute (0: not in Mute, 1: in Mute)
0xA0		0xB8	TRx_State1_A	RO	b0	Reserved
					b1	Reserved
					b2	Link-On (0: not in Link-On, 1: in Link-On)
					b3	Link-Off (0: not in Link-Off, 1: in Link-Off)
					b4	TxFault_SW_A (0: not in TxFault, 1: in TxFault)
					b5	Reserved
					b6	Reserved
					b7	Reserved
0xA0		0xBA	Driver_State_A	RO	b0	TX_FAULT
					b1	TIN_LOS
					b2	TX_LOL
					b3	TX_DIS
					b4	Reserved
					b5	RX_LOS
					b6	RXLOL
					b7	Reserved
0xA0		0xBB	AMCC_State	RO	u08	0x40: fatal, 0x20: fault, 0x10: warn, less than 0x10: good
0xA0		0xBD	TRx_Control_B	WO	b0	Set_TxDisable_B (0: clear TxDisable of RU, 1: set TxDisable of RU)
					b1	Reserved
					b2	Reserved
					b3	Set_Loopback_B (to set optical loopback for RU TRx)
					b4	Set_RxMute_B (to set Rx mute for RU TRx)
					b5	Reserved
					b6	Reserved
					b7	Send_Reqed_B (to read data at designated registers in RU TRx)
0xA0		0xC3	TRx_State0_B	RO	b0	Reserved
					b1	Wavelength Locking (0: unlocked, 1: locked)
					b2	Startup Ready (0: not ready, 1: ready)
					b3	Link Ready (0: not ready, 1: ready)
					b4	Tx Disable (0: not in Tx Disable, 1: in Tx Disable)
					b5	Rx LOS (0: not in LOS, 1: in LOS)
					b6	Loopback (0: not in Loopback, 1: in Loopback)
					b7	Rx Mute (0: not in Rx Mute, 1: in Rx Mute)

Dev Addr	Tab Num	Reg Addr	Reg Name	R/W	Typ	Description
0xA0		0xC6	Driver_State_B	RO	b0	TX_FAULT
					b1	TIN_LOS
					b2	TX_LOL
					b3	TX_DIS
					b4	Reserved
					b5	RX_LOS
					b6	RXLOL
					b7	Reserved
0xA0		0xC8	Req_Dev	WO	u08	Device number (0xA0 or 0xA2) of the starting register to read for RU TRx
0xA0		0xC9	Req_Table	WO	u08	Table number of the starting register to read for RU TRx
0xA0		0xCA	Req_Addr	WO	u08	Address of the starting register to read for RU TRx
0xA0		0xCB	Req_Bytes	WO	u08	Number of Bytes to read from the starting register of RU TRx
0xA0		0xCC ~ 0xEB	Req_DATA	RO	32B	Data read from the designated Registers of RU TRx (max 32 Bytes)
0xA0		0xFD	build_mm	RO	u08	F/W build date: month
0xA0		0xFE	build_dd	RO	u08	F/W build date: date
0xA0		0xFF	build_yy	RO	u08	F/W build date: year
0xA2	0	0x60	MON_BDTEMP_A	RO	u16	SFP case temperature of COT T-SFP
0xA2	0	0x62	MON_VCC_A	RO	u16	Internal supply voltage of COT T-SFP
0xA2	0	0x64	MON_BIAS_A	RO	u16	BIAS current of COT T-SFP
0xA2	0	0x66	MON_TXP_A	RO	u16	TX Optical Power of COT T-SFP
0xA2	0	0x68	MON_RXP_A	RO	u16	RX Optical Power of COT T-SFP
0xA2	0	0x74	MON_MODUL_A	RO	u16	Modulation voltage of COT T-SFP
0xA2	**0**	**0x7F**	**TBSEL**	**RW**	**U08**	**Table Number**
0xA2	1	0xE0	MON_BDTEMP_B	RO	u16	SFP case temperature of RU T-SFP
0xA2	1	0xE2	MON_VCC_B	RO	u16	Internal supply voltage of RU T-SFP
0xA2	1	0xE4	MON_BIAS_B	RO	u16	BIAS current of RU T-SFP
0xA2	1	0xE6	MON_TXP_B	RO	u16	TX Optical Power of RU T-SFP
0xA2	1	0xE8	MON_RXP_B	RO	u16	RX Optical Power of RU T-SFP
0xA2	1	0xF4	MON_MODUL_B	RO	u16	Modulation voltage of RU T-SFP
0xA2	2	0x83	Ch_passwd	WO	u08	Passwd to directly set the channel number into RU T-SFP via I2C
0xA2	2	0xA2	superSTATE	RO	u08	3 = channel search state, 5 = locking state
0xA2	2	0xA4	PWR_level	WO	s08	-1, 0, +1 = reduce Tx power, as is, increase Tx power (by about 1 dB)

Note:
bn: bit position “n”, u08: unsigned char, s08: signed char, u16: unsigned int, nB: “n” Bytes.
RO: Read Only, WO: Write Only, R/W: Read and Write.
xxx_A: control or status for self T-SFP.
xxx_B: control or status for RU T-SFP.

DDM reading formula:
SFP Case Temperature = MON_BDTEMP_A(B) / 256 [oC]
Internal Voltage = MON_VCC_A(B) x 1E-4 [Volt]
Tx Power = MON_TXP_A(B) x 1E-2 [dBm]
Rx Power = MON_RXP_A(B) x 1E-2 [dBm]
Bias Current = MON_BIAS_A(B) [mA]
Modulation Voltage = MON_MODUL_A(B) x 1E-2 [V]

Examples

Channel change

Action		Value	register				Protocol
			Device Addr.	Table No.	Reg. Addr.	Bit No.	
User	Write COT channel number	CHN_A_user	0xA0	N/A	0xB0	N/A	I2C
COT TRx	Send RU channel number to RU	CHN_A_user	N/A				AMCC
Note: Change of COT channel number automatically comes with change of RU channel number.							

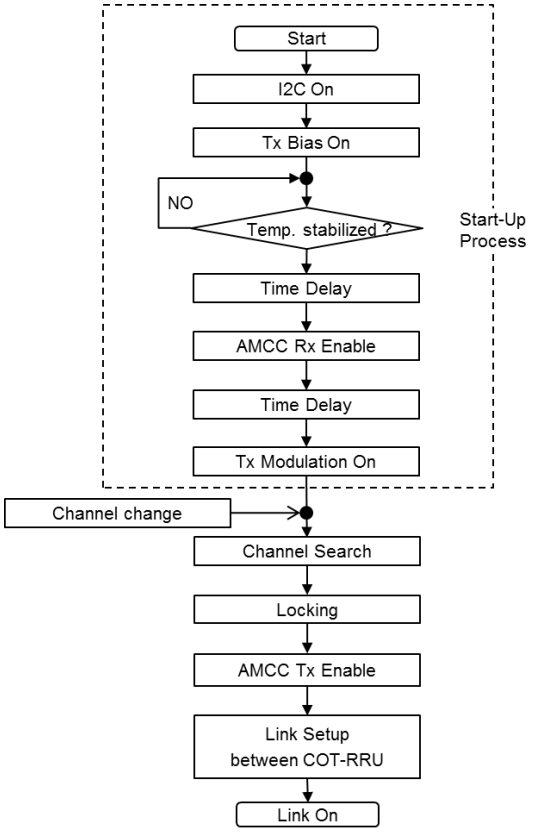
RRU control (e.g. Set RU TRx to be in loopback)

Action		Value	register				Protocol
			Device Addr.	Table No.	Reg. Addr.	Bit No.	
User	Set RRU loopback bit	00001000b	0xA0	N/A	0xBD	b3	I2C
COT TRx	Send the control to RU	00001000b	N/A				AMCC
Note: write 0x08 (1000b) to the register 0xBD.							

RU control (e.g. Set RU Transmitter to be out of TxDisable)

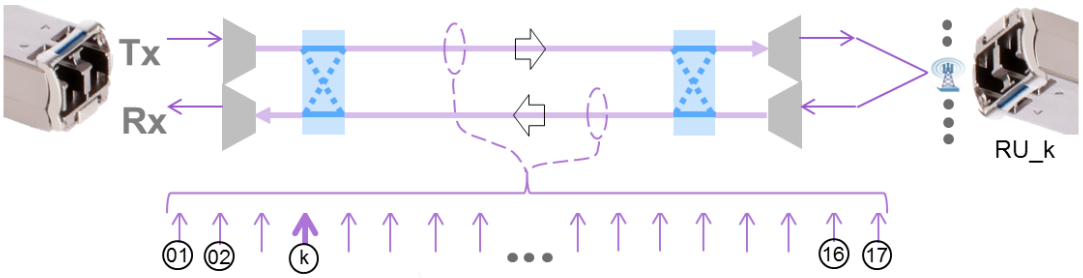
Action		Value	register				Protocol
			Device Addr.	Table No.	Reg. Addr.	Bit No.	
User	Clear RRU TxDisable bit	00000000b	0xA0	N/A	0xBD	b0	I2C
COT TRx	Send the control to RU	00000000b	N/A				AMCC
Note: write 0x00 to the register 0xBD.							

Operation Procedure



Prepared by		Document No.		
BJ KIM, MY PARK		TD-RND-0025 (25G LET spec)		
Reviewed by	Approved by	Date	Rev	Reference
	BW KIM	2021-05-20	V3.0	TD-RND-0010 v2.0

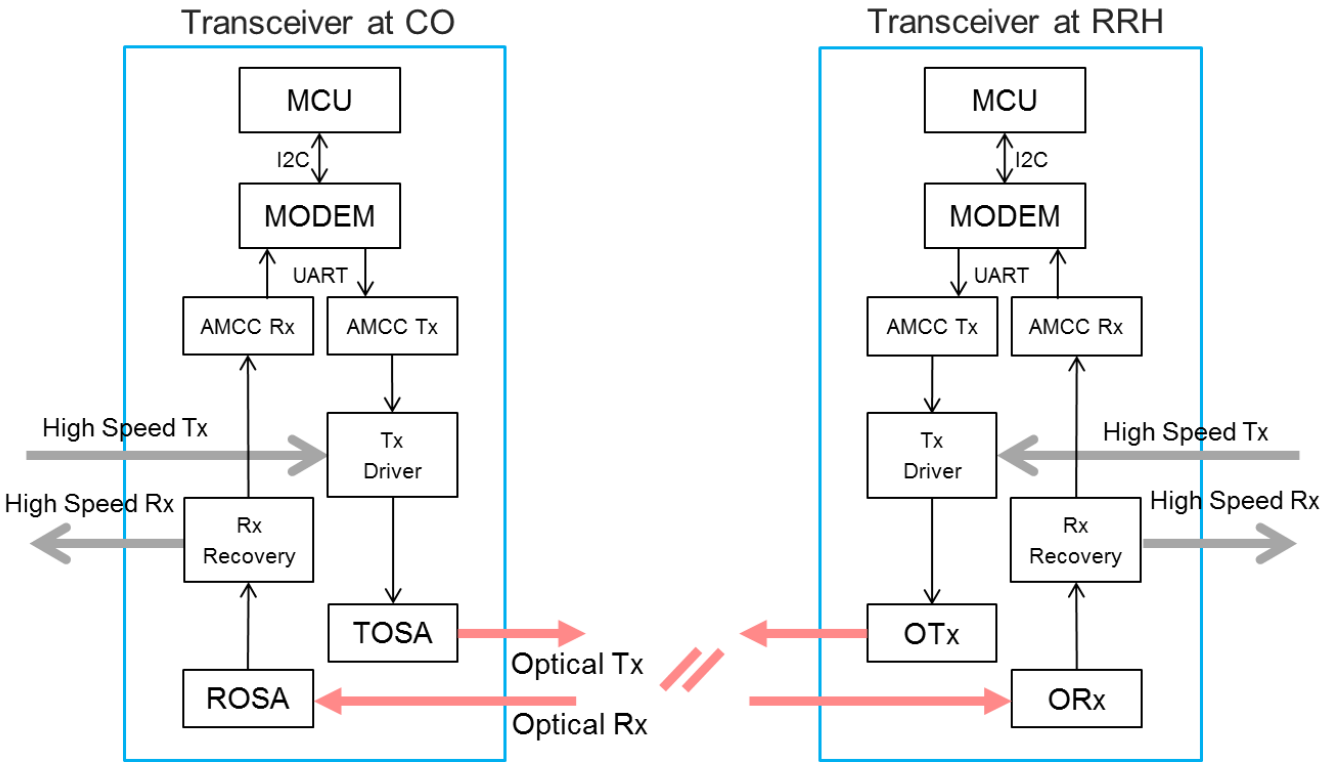
Self Tuning Procedure



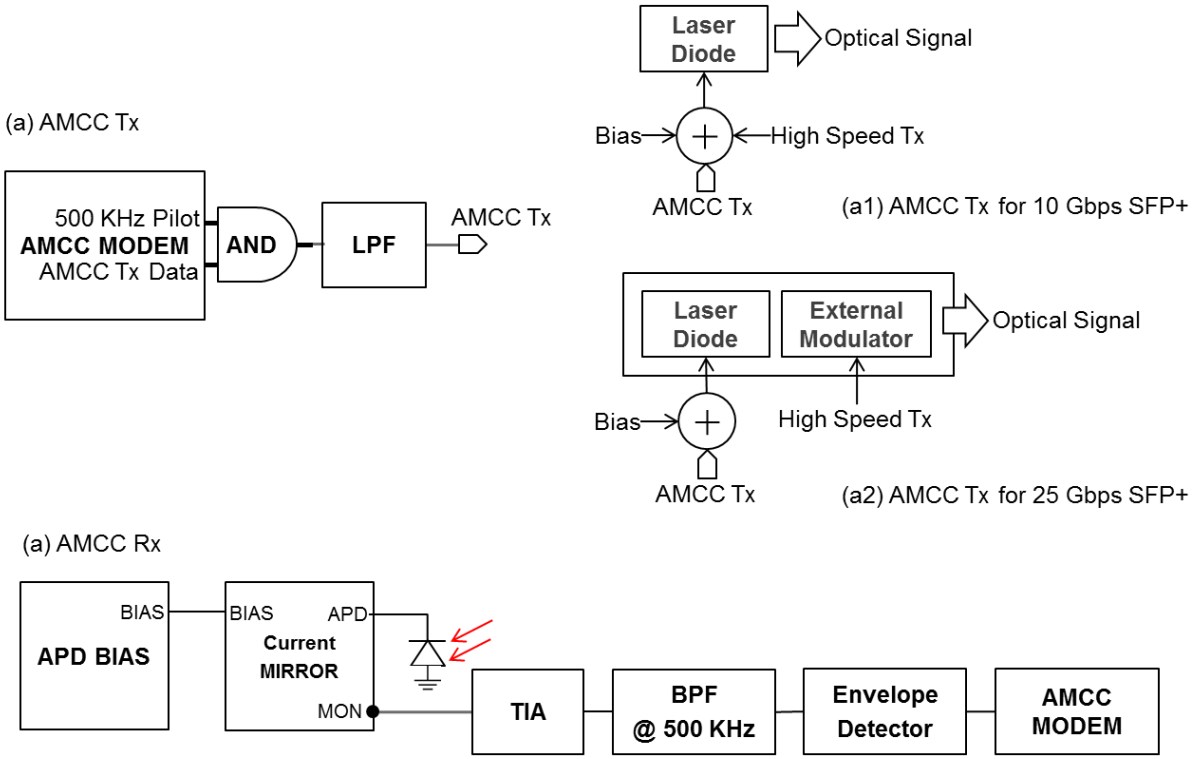
	CO		RU
1	Send PWL① with AWL① .		Wait until arrival PWL and AWL.	1
2	Wait arrival of PWL or AWL for 5 seconds.		Send PWLⓚ and AWLⓚ upon arrival of PWLⓚ and AWLⓚ . STUNE status = Success Go to Locking state	2
3	Repeat 1 & 2 with increased channel numbers			
4	Stop STUNE upon arrival of PWLⓚ and AWLⓚ . STUNE status = Success Go to Locking state			
5	Stop STUNE upon elapse of 5 seconds after PWL(40) & AWL(40). STUNE status = Failure Switch the procedure from STUNE to MTUNE.			
MTUNE: 1) Set PWL (Channel Number) with I2C 2) Check RU STUNE status (to check if CO signal gets to RU)			MTUNE: 1) Switch the procedure from STUNE to MTUNE with I2C 2) Set PWL (Channel Number) with I2C	

PWL: Physical Wavelength, AWL: Wavelength information in AMCC channel, MTUNE: Manual Tuning, STUNE: Self Tuning

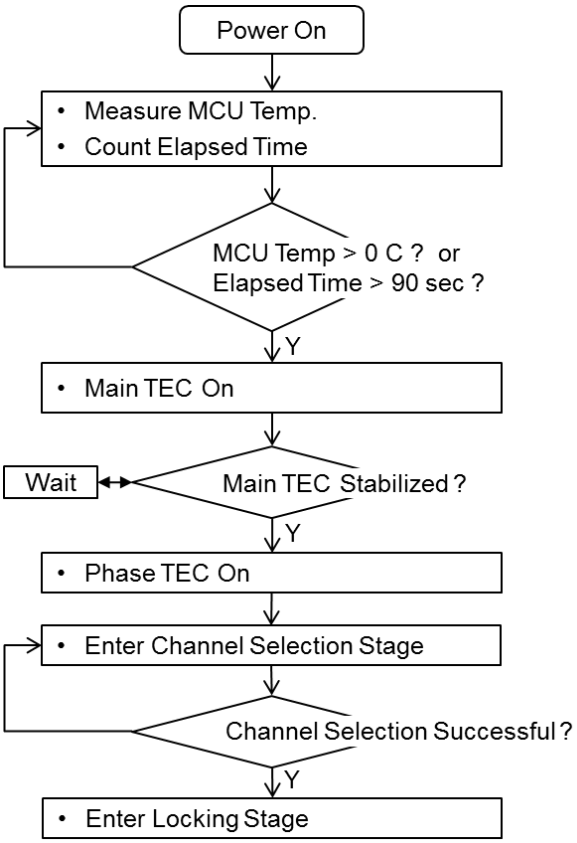
AMCC Functional Structure



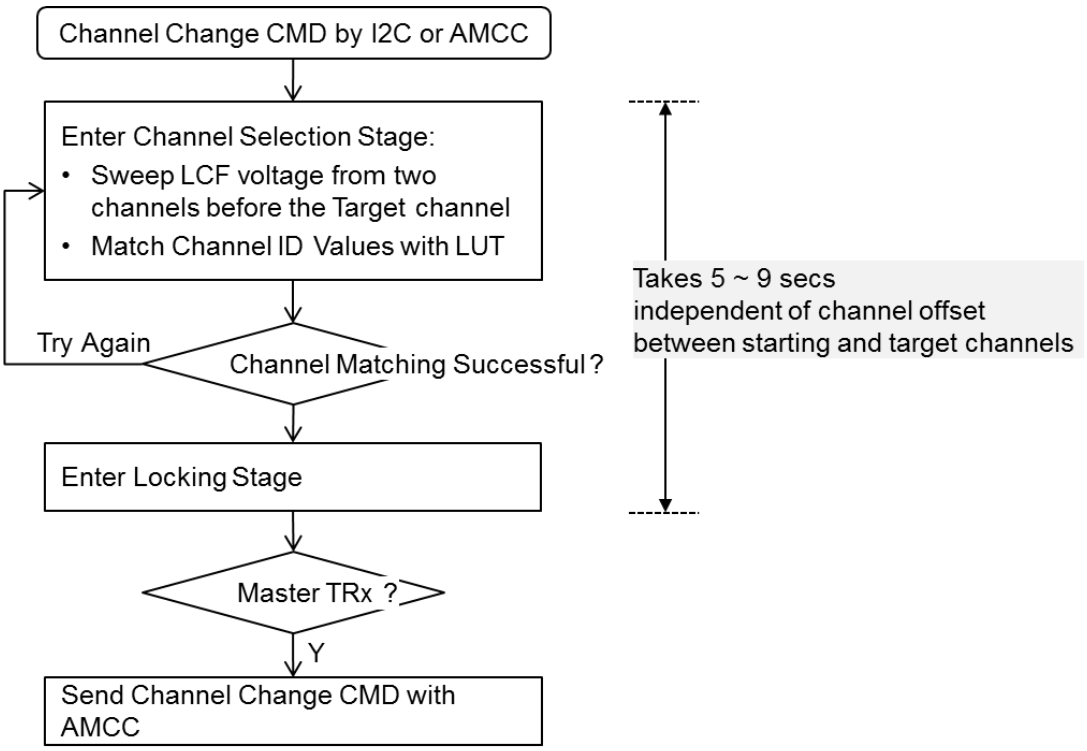
AMCC Hardware Blocks



Cold Start Procedure



Channel Change Procedure



Ordering Information

TBD