

# Implementing TI Retimers on 10G ZR and DWDM SFP+ Optical Links

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## ABSTRACT

The SFF-8431 MSA specification enables 10G Ethernet port side support of various physical media types via the SFP+ module form factor, including the long optical fiber reaches used in telecom routing and optical transport applications. SFF-8431 defines high-speed electrical specifications for multiple SFP+ host-to-module interface types. Of these options, the linear interface type is used to enable optical links of fiber lengths exceeded 40 kilometers. The present document showcases how TI’s retimers, both the 10G and 25G/28G product families, may be used for SFP+ host applications where ZR and DWDM optical links are implemented.

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## 1 Overview of SFF-8431 PMD Types

Table 1 lists the three SFF-8431 SFP+ interface types, along with PMDs generally supported by each one. In addition, Table 1 lists the corresponding SFF-8431 sections defining the host Tx and Rx specifications for each interface type.

**Table 1. SFF-8431 Interfaces and PMD Types**

SFF-8431 SFP+ INTERFACE TYPE	SFP+ PMDs SUPPORTED	SFP+ HOST Tx REQUIREMENTS	SFP+ HOST Rx REQUIREMENTS
Limiting	10GBASE SR – up to 300m OM3 fiber	Section 3.5 “Host Transmitter”	Section 3.5 “Host receiver supporting limiting module”
	10GBASE LR/ER – 10km/40km SMF Direct-Attach Active Optical Cable (AOC) - up to 10m		
	Typical Application - Enterprise and data center switching		
Linear	10GBASE-LRM - OM1 fiber	Section 3.5 “Host Transmitter”	Section 3.5 “Host receiver supporting linear module”
	Linear 10GBASE ZR – 80km SMF		
	Linear 10GBASE DWDM - 80km SMF		
	Typical Application - Switching applications supporting legacy multi-mode fiber, optical routing and transport router links requiring extended SMF reach		
Twinax direct-attach copper cable (10GSFP+ CU)	Passive cables – per SFF-8431, typical lengths up to 5m Active cables – per SFF-8431, typical lengths up to 10m	Section 3.5 “Host Transmitter” plus Appendix E	Appendix E “SFP+ Host receiver supporting 10GSFP+ CU”
	Typical Application - Data Center top of rack switch to server connectivity		

## 2 Device Overview

The SFP+ linear type was primarily defined to enable host implementation of Electronic Dispersion Compensation (EDC) on the 10G Ethernet physical media attachment. EDC functionality serves as the basis of 10GBASE-LRM links. The SFP+ linear type however is also a common Rx topology used for long optical reach SFP+ ZR and DWDM modules. The performance required for the SFP+ host Rx IC is outlined below:

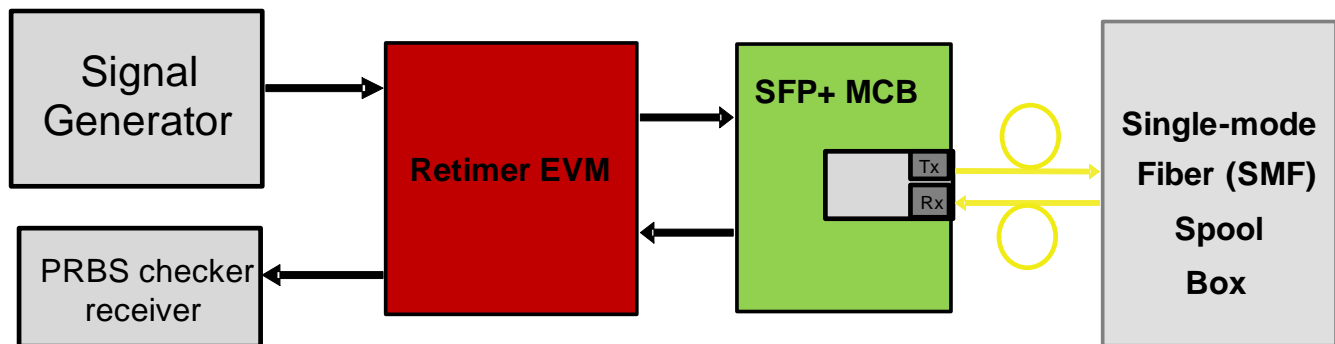
- A linear electrical signal of specified voltage modulation amplitude (VMA) is output by the SFP+ module Rx
- The host is then expected to equalize the full electrical-optical-electrical link (i.e. both electrical and optical domain amplitude distortion and dispersion)
- 10GBASE-LRM involves the use of legacy OM1 fiber, which is bandwidth limited and results in higher dispersion. Given the need to compensate for optical channel effects, EDC is required to meet the BER requirements of 10GBASE-LRM links (as specified by IEEE 802.3aq)
- For linear 10GBASE-DWDM and 10GBASE-ZR links, due to the use of single mode fiber, the optical dispersion effects are less severe than OM1 fiber optical stressors specified for 10GBASE-LRM links. A CTLE-DFE based EQ architecture with sufficient boost can meet the link BER requirements, and EDC is not required

### 3 Device Description

TI's 10G retimer product family includes the following part number families:

- Four channel retimers: DS110DF410, DS110DF410 and DS125DF410
- Two-channel bidirectional retimers: DS100DF111, DS110DF111, and DS125DF111
- 16-channel retimer: DS125DF1610

All of TI's 10G retimers share a similar architecture. Moreover, TI's 10G retimers are designed and tested to meet the requirements of 10G Ethernet port side applications, including the aforementioned SFF-8431 SFP+ interfaces. Such interfaces include limiting and linear optical interfaces as well as direct attach copper (DAC) cables. [Figure 1](#) shows the test setup used to evaluate typical 10G retimer performance when implemented as part of a 10G ZR/DWDM SFP+ link.



**Figure 1. 10G Retimer SFP+ ZR/DWDM Optical Link Test Setup**

For the setup above, the following configurations were used:

- The signal generator provided a 644.53125MHz clock signal, to enable retimer CDR to lock on Both a DS110DF410 and DS110DF111 retimer part number were used
- The retimer PRBS generator was enabled, with Data rate of 10.3125Gbps and PRBS9 pattern used
- Default retimer Tx output settings were used
- Retimer Rx Adapt Mode 2 was used – CTLE with DFE fine tuning
- Both 10G ZR and 10G DWDM SFP+ optical modules were used as part of this evaluation
- An optical link length of 80km was implemented using the single-mode fiber spool box

[Figure 2](#) shows an example 10.3125 Gbps electrical output eye diagram for a 10G DWDM SFP+ module. For this test case an input optical fiber length of 80km was implemented. The SFP+ electrical output eye is open though the voltage modulation amplitude is fairly small, with a value of 31mV.

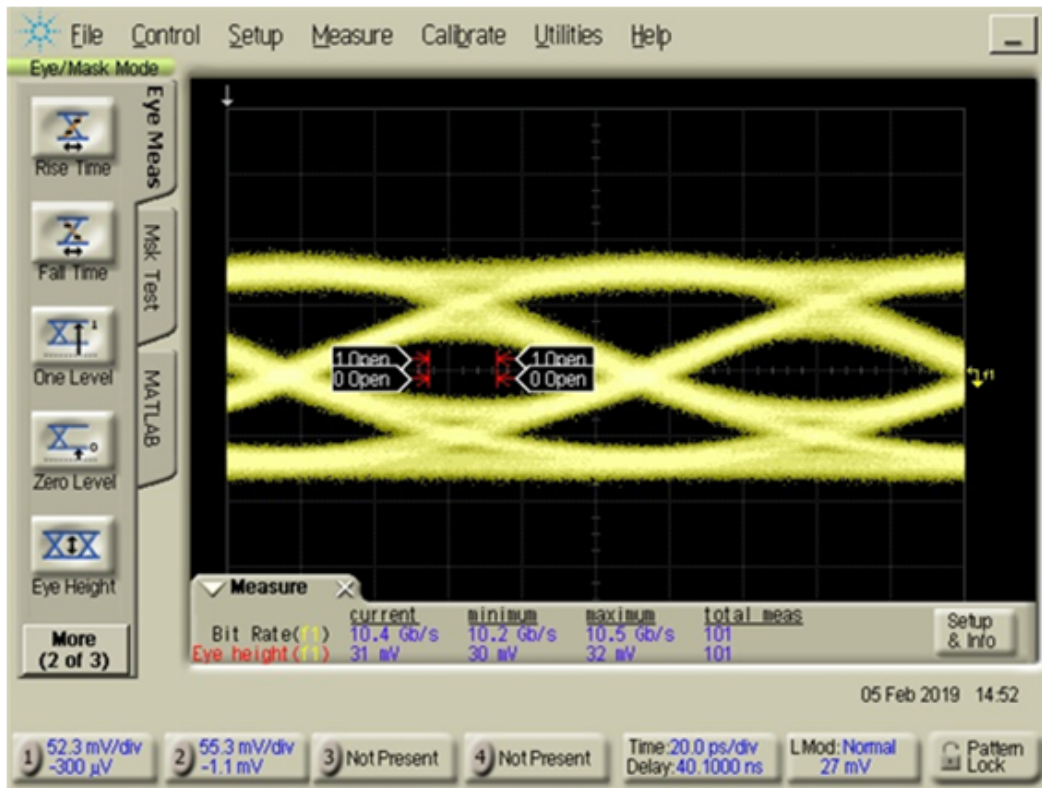


Figure 2. 10G SFP+ DWDM Module Electrical Output for 80km Input Fiber Length, 10.3125Gbps Rate and PRBS9 Pattern

Figure 3 shows an eye capture taken with TI 10G retimer part number DS110DF111 via its Eye Opening Monitor (EOM) function, when its input is fed the SFP+ DWDM electrical output signal per Figure 2. The observed retimer opening values have ample margin to minimum criteria required for error free operation. TI's EOM minimum threshold criteria for retimer input Horizontal Eye Opening (HEO) and Vertical Eye Opening (VEO) to ensure error free links are shown Figure 3.

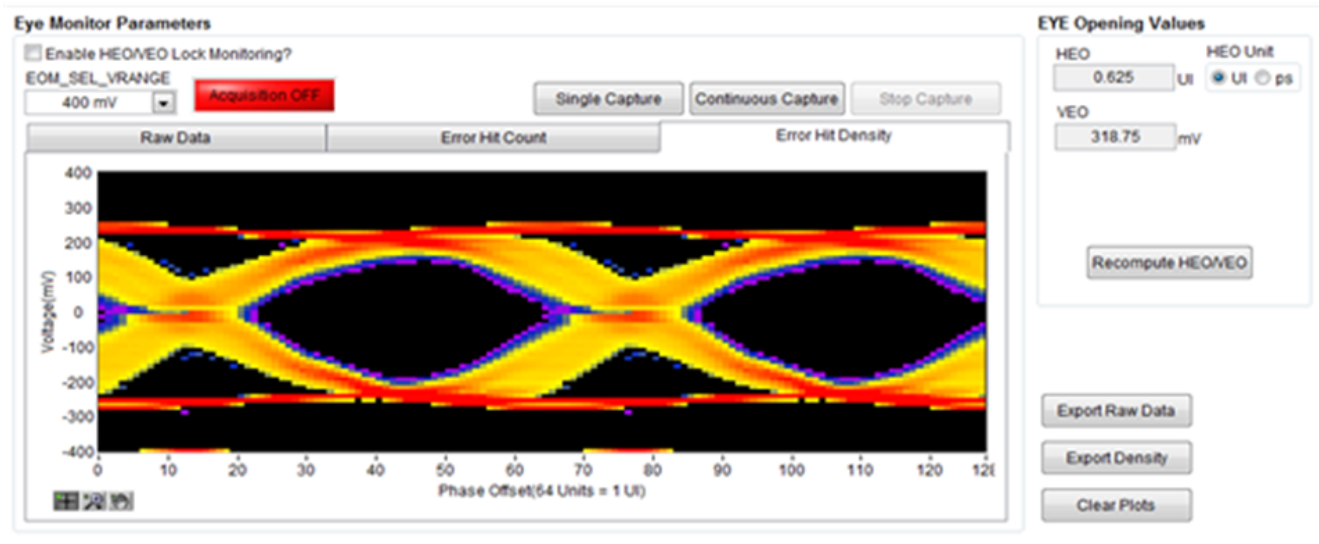


Figure 3. Example DS110DF111 EOM Capture, for Input Signal in Figure 2. Horizontal Eye Opening = 0.625UI, Vertical Eye Opening = 318.75mV

- HEO > 0.375UI
- VEO > 196.875mV

Table 2 summarizes the 10G retimer results obtained as part of the present 10G SFP+ optical link evaluation. The key observations are summarized below:

Table 2. Typical TI 10G Retimer ZR/DWDM SFP+ Optical Link Evaluation Results

RETIMER PART	SFP+ MODULE	LINK DISTANCE	CTLE OUTPUT TYPE	RETIMER HEO (UI)	RETIMER VEO (mV)	Bit ERRORS (4E12 BITS TRANSMITTED)
DS110DF410	ZR	80km	Default	0.5625	287.5	0
DS110DF410	DWDM	80km	Default	0.5625	250	0
DS110DF410	DWDM	80km	Limiting	0.58	356.25	0
DS110DF111	DWDM	80km	Default	0.55	218.75	0
DS110DF111	DWDM	80km	Limiting	0.64	331.25	0

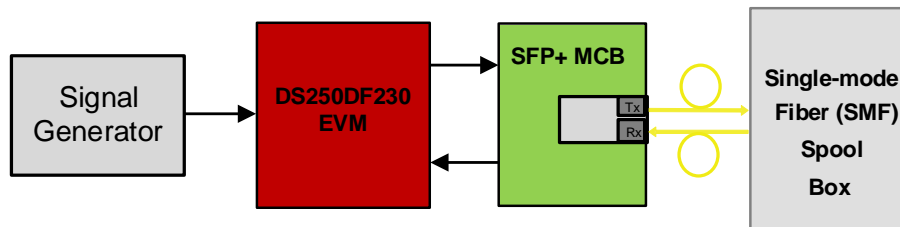
- TI's 10G retimers are able to run error free for all cases evaluated
- The retimer eye opening values exceed the minimum criteria for all cases
- The best eye opening values were observed when the retimer CTLE output was set to limiting mode. This limiting mode means that the retimer output amplitude is fixed to a larger value, and is no longer pure linear representation of the input signal

## 4 Summary

It is not uncommon for 25G system applications to also require 10G rate backwards compatibility. To meet this need, TI's 2G/28G retimers are designed to also support the legacy 10G Ethernet interface requirements. The TI 25G/28G retimer product family includes the following part number families:

- Two-channel retimer: DS250DF230
- Four channel retimer: DS250DF410
- 8-channel retimers: DS250DF810 and DS280DF810

All of TI's 25G/28G retimers share a similar architecture. Moreover, TI's retimers are designed and tested to meet the requirements of 10G Ethernet port side applications, including the aforementioned SFF-8431 SFP+ interfaces. Such interfaces include limiting and linear optical interfaces as well as direct attach copper (DAC) cables. [Figure 4](#) shows the test setup used to evaluate typical 25G/28G retimer performance when implemented as part of a 10G ZR/DWDM SFP+ link.



**Figure 4. 25G/28G Retimer SFP+ ZR/DWDM Optical Link Test Setup**

For the setup above, the following configurations were used:

- The signal generator provided a 644.53125MHz clock signal, to enable retimer CDR to lock
- The DS250DF230 part number was used o The retimer PRBS generator was enabled
- Data rate of 10.3125Gbps, with PRBS9 pattern used
- Retimer PRBS checker function enabled to check for Rx input bit errors
- Default retimer Tx output settings were used
- Retimer Rx Adapt Mode 2 was used – CTLE with DFE fine tuning
- Both VGA off and on settings evaluated

The following optical option were tested:

- Both 10G ZR and 10G DWDM SFP+ optical modules were used as part of this evaluation
- An optical link length of 80km was implemented using the single-mode fiber pool box

[Table 3](#) summarizes the DS250DF230 retimer results obtained as part of the present 10G SFP+ optical link evaluation. The key observations are summarized below:

- Zero bit errors were observed for all cases after transmitting > 4E+12 bits
- TI's minimum threshold criteria for retimer input Horizontal Eye Opening (HEO) and Vertical Eye Opening (VEO) to ensure error free links were met for all cases evaluated (HEO > 0.375UI, VEO > 196.875mV)
- Enabling the Retimer VGA improves the eye opening margin for these 10G SFP+ ZR and DWDM link cases

**Table 3. Typical TI 25G/28G Retimer ZR/DWDM SFP+ Optical Link Results**

SFP+ MODULE	LINK DISTANCE	VGA SETTING	RETIMER HEO (UI)	RETIMER VEO (mV)	BIT ERRORS (4E12 BITS TRANSMITTED)
ZR	80km	Disabled	0.5	246.876	0
ZR	80km	Enabled	0.5625	375	0
DWDM	80km	Disabled	0.5	225	0
DWDM	80km	Enabled	0.5625	368.75	0

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