Application Note

Analog Multiplexer Applications in Optical Modules

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ABSTRACT

As AI computing demands in data centers continue to surge, optical modules are rapidly advancing from 800G and 1.6T, to ultra-high-density form factors such as CPO (Co-Packaged Optics) and XPO[1] (eXtreme density Pluggable Optics) gaining rapid adoption. As system integration continues to scale, the IO resource constraints of core chips such as MCU, ODSP, and AFE are becoming an increasingly prominent bottleneck, making external analog switches an indispensable complement in signal chain design.

Based on the characteristics of TI's analog multiplexers product portfolio and combined with practical optical module design requirements, this application note introduces four typical application scenarios: ePPS timing synchronization, multi-channel signal gating and sampling in silicon photonics systems, bus expansion in XPO platforms, and hot-plug reliability enhancement — providing practical design references for 800G/1.6T and next-generation optical module development.

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Trademarks

1 Introduction

In a typical optical module system, there are multiple signals that need to be connected, processed and controlled.

- Analog Current Sensing: MPD, RSSI
- Analog Voltage Sensing: NTC
- Bus Protocol: I2C, I3C, SPI
- MSA Protocol: INT/RST, LPW/PRS/ePPS

With optical communication rapidly advancing in technology and growing in demand, IO resources of MCU/DSP/AFE may lack the capability in signal processing handling. This brings challenges of integration gaps for implementing new standards with compact size form factors.

TI's multiplexers and switches portfolio is one of the most comprehensive analog switch suppliers in the industry to help provide solutions to combat challenges in the surging optical networking space.

2 Typical User Cases in Optical Modules

2.1 ePPS Signal Multiplexing - TMUX131

Modern data center switches and telecom systems rely on IEEE 1588 PTP to achieve nanosecond-level time synchronization. The PPS signal from the switch host is fed into the optical module to align the module's time domain with the system-level PTP clock. This ensures all modules remain time-aligned, which is critical for coherent beamforming, phase matching, and data integrity across parallel optical channels. The adoption of ePPS functionality marks a significant evolution of OSFP-XD[3] — transitioning from a simple data transceiver to a timing-aware intelligent optical module capable of participating in precisely synchronized network architectures.

Per protocol specification, the ePPS signal is multiplexed onto the OSFP LPWn/PRSn pins. As shown in Figure 2, the TMUX131 (2-channel, 1:3) is used to multiplex and select between the LPW and ePPS signals sent from the host to the module, routing them respectively to the MCU and ODSP bidirectionally. With an on-state capacitance of only 1.3pF and a propagation delay of 50ps, TMUX131 ensures highly accurate ePPS signal transmission, including higher slew rate and lower delay.

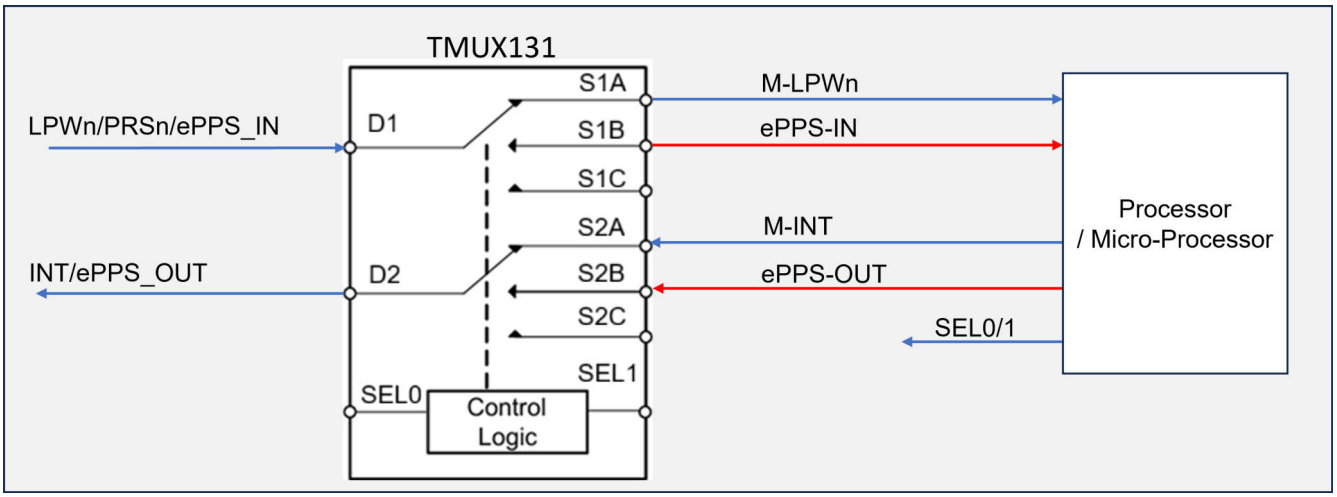

Figure 2-1. PPS implementation by TMUX131

Design Note

1. ePPS signal transmission demands extremely high timing accuracy and tight rise/fall time requirements. When introducing a multiplexer into the signal path, careful attention must be paid to the parasitic capacitance of the device to ensure sufficient fast edge transitions and maintain system-level ePPS alignment precision.
2. Off Isolation would be another design consideration, in case the high slew rate brings unwanted signals to un-selected channel.
3. TMUX1511[4] (4-channel, 1:1) and TMUX136[5] (2-channel, 1:2) offer comparable performance parameters with small form factors, providing additional flexibility for different system design requirements.

2.2 Multi-Channel Analog Signal Sampling - TMUX1108[6] / TMUX1104

Given the diversity of silicon photonics architectures, AFE integration levels, and cost considerations, a wide variety of AFE solutions exist in the market. In cases where the number of built-in MUXIN inputs of an AFE is insufficient to cover all required analog signal channels, external analog switches can complement the design. By combining a cost-effective 12-channel analog input AFE with external 8:1 expansion, the total analog sampling capacity can be extended to up to 40 channels.

Use case #1: In a 1.6T (8-Lane) silicon photonics module, 8 silicon photonic modulators generate a total of 32 MPD/RSSI signals (24 MPDs + 8 RSSIs). Using TMUX1108/TMUX1104 to assist the AFE, the analog signal sampling system can support up to 40 current/voltage signal inputs, offering a flexible architecture that can be adapted to various MCU/AFE platform combinations.

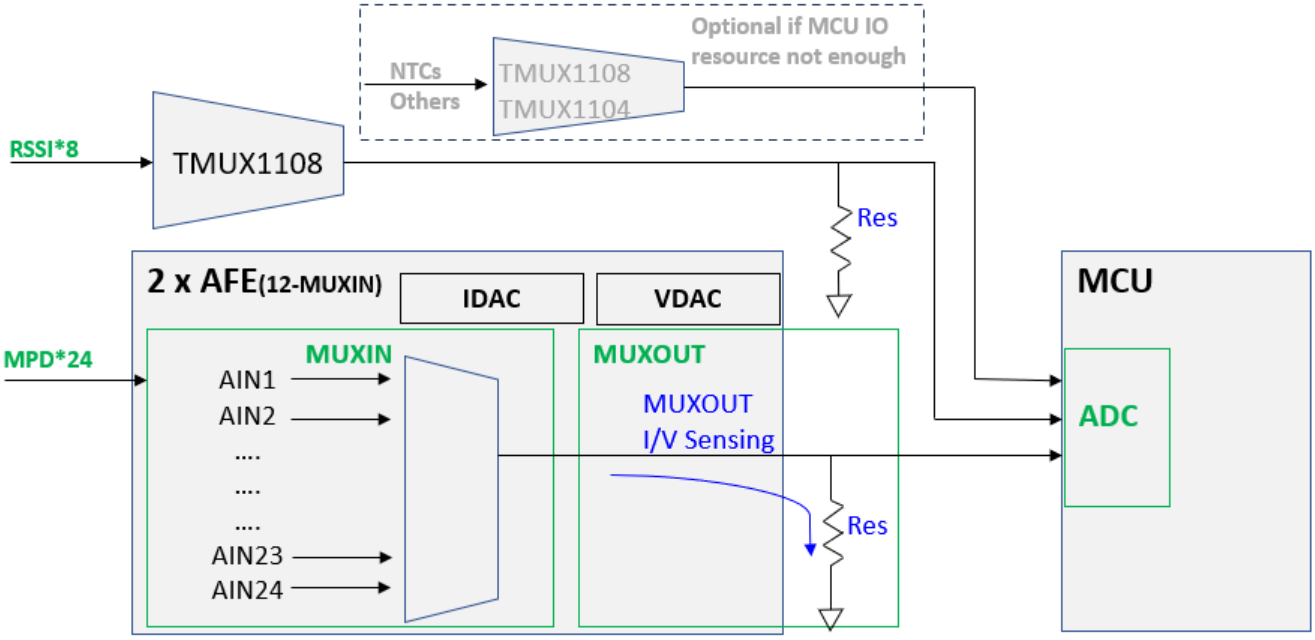

Figure 2-2. Signal Sampling Chain Diagram 1.6T (8-Lane) Optical Module Sipho Based

Use case #2: In an 800G (4-Lane) silicon photonics module, 4 silicon photonic modulators generate 16 MPD/RSSI signals (12 MPDs + 4 RSSIs). In this case, a single TMUX1104 paired with a 12-channel AFE is sufficient to achieve full analog signal sampling and channel selection coverage.

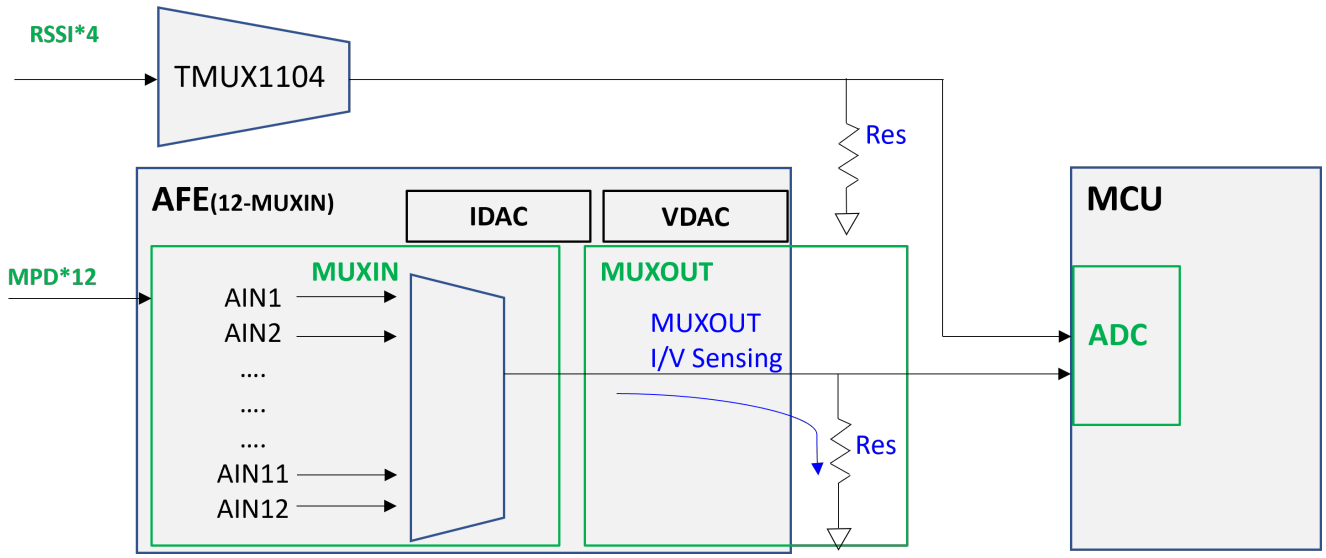

Figure 2-3. Signal sampling chain diagram 800G (4-Lane) optical module Sipho based

As illustrated by both scenarios, using an External analog multiplexer to expand analog input channels offers a compelling advantage in terms of cost efficiency and resource utilization compared to adopting a higher-integration AFE or MCU. Furthermore, analog multiplexers provide greater design flexibility when developing 800G, 1.6T, and even 3.2T optical modules.

Design Note: Leakage current is a critical specification for multiplexers in this applications. MPD and RSSI signals being switched are weak current signals (typically in the µA to mA range), the primary selection criterion for the analog switch is its leakage current in both on and off states, ensuring no significant impact on signal integrity. Taking TMUX1108 as an example, its 3pA leakage current represents an excellent specification — significantly better than the internal switch leakage of most AFEs. Its compact 2.6mm × 1.8mm package makes it highly suitable for multi-channel, low-current sampling applications, including standalone use independent of the AFE.

2.3 I2C/SPI 1:4 Bus Expansion in XPO- TMUX1309A

XPO is an ultra-high-density pluggable optical module form factor, currently supporting an aggregate bandwidth of 12.8T, implemented via 32 lanes at 1.6T per lane. Unlike conventional pluggable modules, XPO requires a single MCU to manage and control 4 DSPs, placing significant demands on MCU IO resources. For I2C bus expansion, as shown in Figure 3, implementing a 2-channel 1:4 analog switch using TMUX1309A is a highly practical solution. Its high bandwidth accommodates future I2C/I3C high-speed requirements, and it comes in a compact QFN package.

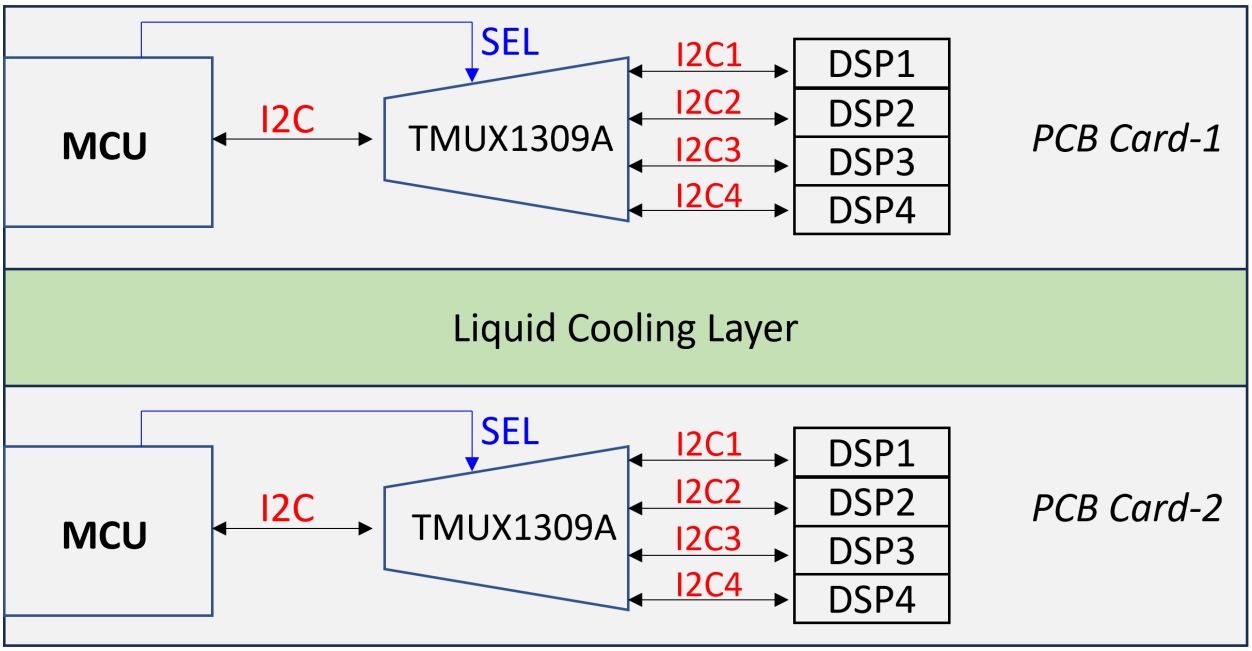

Figure 2-4. Simplified I2C Bus block diagram in XPO

Design Note:

1. When selecting a solution for this application, key considerations include the required switching mode and the supported data transmission bandwidth to ensure compatibility with current and future protocol speeds.
2. TI also offers TCA9846[9], a dedicated 4-channel I2C switch supporting up to 1MHz data rate, as an alternative solution. 1:4 selection achieved by embedded protocol.
3. If there is a need to implement 1:4 SPI switch, then using two units of TMUX1309A is a good option.

3 Summary

As optical modules rapidly evolve toward 800G, 1.6T, and the ultra-high-density XPO form factor, the complexity of internal signal chains continues to escalate, and IO resource constraints on core chips such as MCU, ODSP, and AFE are becoming increasingly critical. TI's analog multiplexers, backed by excellent performance specifications and a comprehensive product portfolio, provide optical module designers with flexible, cost-effective, and highly reliable signal chain expansion solutions.

4 References

1. XPO, https://xpomsa.com/, webpage.
2. Texas Instruments, TMUX131, product page.
3. OSFP-XD https://osfpmsa.org/, webpage.
4. Texas Instruments, TMUX1511, product page.
5. Texas Instruments, TMUX136, product page.
6. Texas Instruments, TMUX1108, product page.
7. Texas Instruments, TMUX1104, product page.
8. Texas Instruments, TMUX1309A, product page.
9. Texas Instruments, TCA9846, product page.
10. Texas Instruments, Analog Switches & Muxes | TI.com, product page.

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