OPDM-64

Optical Programmable Delay Module

User Manual

Version 1.0

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1 Specifications

Operating wavelength	1260-1640 nm
Optical delay range	0 to 64 ns
Optical delay resolution	±0.001 ps
Optical delay accuracy	±0.01 ps
Optical delay repeatability	±0.01 ps
Delay setting speed	< 2.5 s [1]
Latency (own delay)	12.5 ns
Insertion loss	7.05 dB [2]
Insertion loss variation	±0.1 dB
Return loss	50 dB
Optical power max	300 mW
Power supply	12 VDC / 1 A
Control modes	Front panel controls, Ethernet
Operating temperature	0 °C to 40 °C
Storage temperature	-20 °C to 60 °C
Fiber type	Corning SMF-28
Durability	> 10^9 cycles
Dimensions	Standard rack 1U, 200 mm depth

Notes.

1. Delay setting speed is ~ 50-300 ms when delay change is a multiple of 0.5 ns, otherwise less than 2.5 s, see details in Device overview.
2. Value at 25 °C and 1550 nm.

2 Device overview

Optical Programmable Delay Module (OPDM-64) provides precise optical signal delay in range 0 to 64 ns with 1 fs resolution. The instrument has low optical insertion loss and reduced delay latency of only 12.5 ns. A unique feature of the instrument is an internal equalization of delay and attenuation. Together with temperature compensation of the delay it results in nearly constant insertion loss and delay accuracy over the whole delay and temperature ranges (see Specifications).

OPDM-64 can be controlled manually via its front panel or remotely with Ethernet interface.

Fig. 1. OPDM-64 general view.

2.1 Delay switching speed

The OPDM-64 delay line consists of eight miniature MEMS 2x2 full switches, which form 7 delay bits (0.5ns, 1ns, 2ns, 4ns, 8ns, 16ns and 32ns) and a precise opto-mechanical continuous delay line for delays shorter than 0.5 ns. Overall delay switching speed depends on switches' activation time (50 ms) and a movement speed of the opto-mechanical delay (256 ps/s). Therefore, in case of delay change of multiple of 0.5 ns the switching speed is minimal, but still longer than 50 ms due to delay compensation mechanism. Otherwise switching speed is determined by the opto-mechanical delay speed, in this case maximum switching time is ~2.5 s.

2.2 Delay equalization

The switches provide delays by routing the light via optical fiber paths with different lengths, which can be cut with 1 mm (or ~4.9 ps) accuracy on the best average. Thus, the absolute error for 7-bit delay could easily exceed 35 ps. In OPDM-64 this error for each delay bit is compensated by the opto-mechanical delay line, resulting in 0.01 ps delay accuracy.

The other source of delay error is an outside temperature change. A standard single-mode optical fiber suffers from a propagation time temperature sensitivity of 39 ps/km/K at 1550 nm wavelength. For OPDM-64 with 12.5 ns intrinsic delay and 64 ns maximum delay this error could be as much as 0.6 ps/K. In order to compensate for temperature dependence, the device is equipped with a temperature sensor. The data from the sensor is used at each delay bit for temperature compensation by opto-mechanical delay as well as for compensation of the device latency (own device delay, i.e. when its delay is set to 0 ns).

The delay equalization is applied every time user changes the delay. In addition to that, the temperature is measured periodically with a given time interval in order to detect changes. Whenever the temperature change exceeds 0.5 °C, the equalization applied to provide constant device delay over time. The temperature is measured every 10 min by default, the interval can be changed via dedicated remote command (see Remote control and programming).

Both compensations due to path length mismatches and temperature changes can be turned off or on remotely. When both are off the compensation delay is not added, so the overall delay latency is minimal.

N.B. Please consider that despite the accurate equalization there is always an independent slight parameter drift over time due to internal mechanical movements and wear. Therefore, it is expected to have slight changes and deterioration of equalization over time even under constant environmental conditions. This can be fixed by recalibration of the device by the manufacturer.

2.3 Insertion loss equalization

Optical switches, that form the delay bits, have slight insertion loss (IL) variation, moreover each switch has different IL for different routes together with splices IL differences for every passage. So overall IL could change significantly for every single bit. In order to compensate for this effect and equalize the IL for every bit, the device is equipped with a small optical attenuator.

Besides switches, the opto-mechanical continuous delay introduces additional IL, depending on the value (with minimum at 0 ns and maximum of ~0.5 dB at 0.5 ns). This effect is also compensated with the built-in attenuator.

The described measures provide overall IL variation of 0.1 dB.

Insertion loss compensation can be turned off or on remotely. When it is off the compensation attenuation is not added, so the overall device attenuation is minimal.

3 Device operation

3.1 Power supply

OPDM-64 requires a 12V/1A DC power supply to operate. A standard AC/DC power supply adapter is shipped with the instrument. If another DC power supply is going to be used, the DC power supply connector should have correct polarity: the center pin is positive (+) and the outer contact is negative (-). Please check power supply output voltage and polarity before connecting it to power line when using third-party power supply. Incorrect voltage and/or polarity will damage the instrument.

3.2 Start of operation

Check the DC power supply output voltage (12 V DC) and polarity (center positive). After power supply connection, turn on the power switch. The green LED power indicator should light up. During initialization the LCD will display a loading screen, after which screen with delay setting will show up. Connect fiber pigtails, the input and output fiber pigtails are interchangeable. Please keep in mind that OPDM-64 always transmits optical signal, even when disconnected from the power line. Therefore, be careful with the instrument's open output, when there is already a connected optical input signal.

After restarting OPDM-64 will keep all the settings, that were set during operation.

3.3 Front panel overview

After loading OPDM-64 can be easily controlled directly via its front panel:

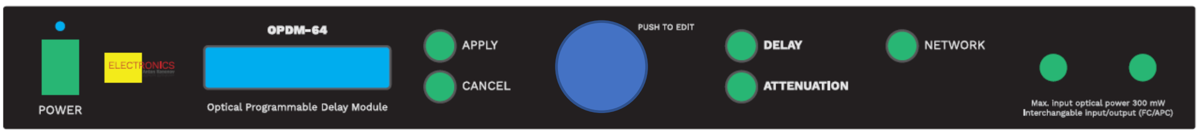

Fig. 2 OPDM-64 front panel

There are three main settings that can be viewed and edited from the front panel: delay, attenuation and network addresses, each setting is accessible with a corresponding button.

OPDM-64 can be either in a *view mode* or in an *edit mode*. In the *view mode* the current value of the chosen main setting is displayed. In the *edit mode* user can change the value and either apply it or revert to the previous one.

General control logic is following:

- To enter *view mode*: choose the desired setting with the control button (<DELAY>, <ATTENUATION> or <NETWORK>)
- To enter *edit mode* press <KNOB>
- To exit *edit mode* press <CANCEL> or any other control button

In the *edit mode*:

- Cycle through the value ranges by pressing the <KNOB> button
- Edit the value by rotating the knob
- To apply new value press <APPLY>, to cancel and revert to the previous value – press <CANCEL> or any other control button

Below is more detailed description of the control buttons.

<DELAY>

Pressing DELAY button allows user to view and edit the delay of the device. After pressing the button an LCD changes to the following screen:

```
DELAY:
63.950,333 ps
```

The delay value is shown in picoseconds, so the value shown in the figure is 63 950,333 ps or equivalently 63,950333 ns. In the *edit mode* user can cycle through ns, ps and fs ranges by pressing the knob, current range is highlighted with the cursor. After editing press <APPLY> to set a new value or <CANCEL >to revert to the value before editing.

<ATTENUATION>

Pressing ATTENUATION button allows to view and edit the attenuation of the device. After pressing the button, the LCD changes to the following screen:

```
ATTENUATION:
16,91 dB
```

The attenuation value is shown in decibels. In the *edit mode* user can cycle between integer and fractional parts. After editing press APPLY to set a new value or CANCEL to revert to the previous one.

<NETWORK>

Pressing NETWORK button allows to view and edit network settings of OPDM-64. By subsequent pressing the <NETWORK> user cycles the settings for IP address, subnet mask and IP address of default gateway. The corresponding views of the LCD are presented in the following figure:

IP ADDRESS: 10.0.0.22	MASK: 255.255.255.0	GATEWAY: 10.0.0.22

In the *edit mode* user can cycle between the octets of the IP address or subnet mask. After editing press APPLY to set a new value or CANCEL to revert to the previous one.

4 Remote control and programming

OPDM-63 can be remotely controlled with the Ethernet interface.

For remote control OPDM-64 must be connected via the Ethernet interface to a common network with TCP/IP network protocol.

A default port for TCP/IP communication is 23.

The instrument can be controlled with the Telnet protocol or using the standard network drivers of your operating system (“socket” or “winsocket”).

OPDM-64 provides following commands for remote control:

Command:	**Short description:**
DELAY `<Val>`	Sets the delay value to <Val> ps
DELAY?	Queries current delay value in ps
DELAY:EQ `<Val>`	Switches delay equalization ON or OFF
DELAY:EQ?	Queries status of delay equalization
ATT `<Val>`	Sets the attenuation value to <Val> dB
ATT?	Queries current attenuation value in dB
ATT:EQ `<Val>`	Switches attenuation equalization ON or OFF
ATT:EQ?	Queries status of attenuation equalization
TEMP?	Queries instrument’s temperature
TEMP:EQ `<Val>`	Switches the delay compensation due to temperature change ON or OFF
TEMP:EQ?	Queries the state of delay compensation due to temperature change
TEMP:EQ:INTERVAL `<Val>`	Sets the time interval for automatic delay compensation due to temperature change
TEMP:EQ:INTERVAL?	Queries the time interval for automatic delay compensation due to temperature change
IP?	Queries for instrument’s IP address
IP `<Val>`	Sets instrument’s IP to <Val>
MASK?	Queries for instrument’s subnet mask
GATEWAY?	Queries for instrument’s default gateway IP address
***IDN?**	Queries the instrument identification string

For detailed description of the commands please refer to description of commands for remote control.

To unambiguously distinguish commands sent via TCP/IP a so-called message framing is used. Every command must be terminated with a newline escape sequence “\n”, for example: ATT?\n. Each response is also terminated with “\n”.

OPDM-64 responses to every sent command. If the command is a query (e.g. “IP?”) the response is a string, containing a value. If the command sets a value (e.g. “ATT 10.1”) the response is either “0” (the value was not set) or “1” (the value was successfully set). To any other command the response is a string containing an error message.

The commands are case sensitive, so “IP?” and “ip?” are different commands.

4.1 Commands for remote control

DELAY `<Val>`

Changes the delay value to <Val> ns.

`<Val>` is the delay value in ps between 0ps and 64000ps with resolution of 0.001ps.

Response <1> if delay was set and <0> if it was not.

Example:

Command:

```
DELAY 64125.2\n
```

Response:

```
1\n
```

DELAY?

Queries current delay value in ps.

Example:

Command:

```
DELAY?\n
```

Response:

```
64125.2\n
```

DELAY:EQ `<Val>`	Changes the delay equalization setting ON or OFF. When OFF the correction delay is not added, which minimizes the overall device latency.
	
	`<Val>` is either 0 or 1.
	0 – do not correct delay, 1 – apply delay correction.
	
	Response <1> if delay equalization was set and <0> if it was not.
	
	Example:
	
	Command:
	`DELAY:EQ 0\n`
	Response:
	`1\n`

DELAY:EQ?	Queries delay equalization state. Returns 0 if equalization of OFF and 1 if it is ON.
	
	Example:
	
	Command:
	`DELAY:EQ?\n`
	Response:
	`0\n`

ATT `<Val>`	Changes the attenuation value to <Val> dB.
	
	`<Val>` is the attenuation value in dB between 0dB and 30dB with resolution of 0.01dB.
	
	Response <1> if attenuation was set and <0> if it was not.
	
	Example:
	
	Command:
	`ATT 25.35\n`
	Response:
	`1\n`

ATT?	Queries current attenuation value in dB.
	
	Example:
	
	Command:
	`ATT?\n`
	Response:
	`25.35\n`

ATT:EQ <Val>	Switches the attenuation equalization setting ON or OFF. When OFF the correction attenuation is not added, so the minimum possible overall attenuation is used.
	
	<Val> is either 0 or 1. 0 – do not correct attenuation, 1 – apply attenuation correction.
	
	Response <1> if attenuation equalization was set and <0> if it was not.
	
	Example:
	
	Command:
	`ATT:EQ 0\n`
	Response:
	`1\n`

ATT:EQ?	Queries attenuation equalization state. Returns 0 if equalization of OFF and 1 if it is ON.
	
	Example:
	
	Command:
	`ATT:EQ?\n`
	Response:
	`0\n`

TEMP?	Queries instrument’s temperature. Returns current temperature in °C.
	
	Example:
	
	Command:
	`TEMP?\n`
	Response:
	`34.17\n`

TEMP:EQ <Val>

Switches the delay compensation due to temperature change ON or OFF. When OFF the correction delay is not added, which minimizes the overall device latency.

<Val> is either 0 or 1.
0 – do not correct delay, 1 – apply delay correction.

Response <1> if delay equalization due to temperature change was set and <0> if it was not.

Example:

Command:

```
TEMP:EQ 0\n
```

Response:

```
1\n
```

TEMP:EQ?

Queries the state of delay compensation due to temperature change. Returns 0 if delay compensation of OFF and 1 if it is ON.

Example:

Command:

```
TEMP:EQ?\n
```

Response:

```
0\n
```

TEMP:EQ:INTERVAL <Val>

Sets the time interval for automatic delay compensation due to temperature change.

<Val> is the time interval in seconds.

Response <1> if the interval was set and <0> if it was not.

Example:

Command:

```
TEMP:EQ:INTERVAL 600\n
```

Response:

```
1\n
```

TEMP:EQ:INTERVAL?	Queries the time interval for automatic delay compensation due to temperature change. Returns the time interval in seconds.
	
	Example:
	
	Command:
	`TEMP:EQ:INTERVAL?\n`
	Response:
	`600\n`

IP?	Queries instrument's IP address. Returns current IP address as string.
	
	Example:
	
	Command:
	`IP?\n`
	Response:
	`10.0.0.22\n`

IP <Val>	Sets instrument's IP address.
	
	<Val> is a string with a new IP address in a traditional form (e.g. 10.0.0.5)
	
	Response <1> if IP address was set and <0> if it was not.
	
	Example:
	
	Command:
	`IP 10.0.0.5\n`
	Response:
	`1\n`

MASK?	Queries instrument's subnet mask. Returns current subnet mask as string.
	
	Example:
	
	Command:
	`MASK?\n`
	Response:
	`255.255.255.0\n`

`GATEWAY?`	Queries instrument's default gateway IP address. Returns gateway IP address as string.
	
	Example:
	
	Command:
	`GATEWAY?\n`
	Response:
	`10.0.0.1\n`

`*IDN?`	Queries the instrument identification string, which includes the instrument type, its serial number, and the software revision.
	
	Example:
	
	Command:
	`*IDN?\n`
	Response:
	`OPDM-64,ADNSFS001,rev1.1\n`